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TEXT-BOOK

OF

ANATOMY

EDITED BY

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TO

Sir William Turner, K.C.B.

F.R.S., M.B., LL.D., D.C.L., D.SC.,

IN RECOGNITION OF

HIS EMINENCE AS AN ANATOMIST

AND HIS INFLUENCE AS A TEACHER

THIS VOLUME

IS DEDICATED

BY THOSE OF HIS FORMER PUPILS AND ASSISTANTS

WHO HAVE CONTRIBUTED

TO ITS PAGES

PREFACE TO THE SECOND EDITION.

The gratifying reception given to the Text-book of Anatomy, not only in this country but also in America, has rendered it necessary to prepare a new edition. In carrying out this work the whole book has been carefully revised, and a large number of new illustrations have been added.

The sections in which the chief changes and additions have been made are those upon Embryology, the Joints, the Muscles, the Brain and Spinal Cord, the Genito-Urinary Organs, the Lymphatics, and Applied Anatomy. By pruning down in various directions, it has been found possible to incorporate a considerable amount of new matter in these and other sections without materially increasing the bulk of the book.

The lamented death of Professor Birmingham was felt by all the contributors to be not only a personal loss, but one which materially affected an important section of the book. Although in very bad health, Professor Birmingham was desirous to undertake his share of the work, and he had the sheets on the Digestive System in his possession for this purpose when he died. There was probably no part of the book which required less revision than his, and the Editor has taken upon himself the duty of making the alterations which seemed essential. In doing this he has been careful to avoid unnecessary changes and to preserve throughout the original character of the article.

In the section upon the Muscular System, a series of illustrations has been added in which the areas of muscle attachment are delineated upon the bones. For the preparation of the specimens, and for assistance in the mapping out of these areas, the Editor is indebted to Dr. E. B. Jamieson. Those who have attempted work of this kind will appreciate the amount of labour and judgment entailed, as it is only by taking the average condition in many specimens, and by the close study of the bones selected for the delineations, that a sufficiently accurate result can be attained.

With the exception of the figures which have been added to the sections of the book dealing with Embryology, Osteology, and the Genito-Urinary Organs, the many new illustrations which appear in this edition have been prepared in the Anatomical Department of the University of Edinburgh. In carrying out this work, the Editor has again had the good fortune to secure the co-operation of Mr.

J. T. Murray, an artist whose ability in the rendering of anatomical subjects is recognised on all hands. Wherever it was felt that colour would increase the artistic effect or the general usefulness of an illustration, it has been freely employed, both in the case of the old and of the new figures.

The Editor cannot conclude this preface to the second edition of the Text-book without expressing his grateful acknowledgment of the assistance which has been so freely extended to him by his fellow-contributors at every stage of the work. He has also to thank many readers of the first edition for calling his attention to typographical errors and other imperfections which had escaped his notice in passing the sheets through the press.

18 Grosvenor Crescent, Edinburgh,
August 1905.

PREFACE TO THE FIRST EDITION.

THE form which this book has taken expresses the desire of those who have contributed the various sections to produce something which they might dedicate to their former teacher and master, Sir William Turner. With one exception, all the contributors have studied under Sir William Turner, and all but two have for longer or shorter periods acted as his Assistants. Bound together by this common tie, and animated by affection and reverence for their great master, they have sought to produce a book worthy of him whose teaching it so largely reflects, and if this object has not been attained it is not for want of will, but of power, on the part of the writers.

In the preparation of a work such as this it is no easy matter to prevent overlapping of the different articles and to keep the various sections in harmony with each other. Yet in this direction it is believed that a fair amount of success has been attained. Differences of opinion on particular points were bound to arise, but the Editor found in those concerned the greatest readiness to come to a mutual understanding, and he is deeply grateful to his colleagues for the manner in which they endeavoured to lighten his work and assist him in his task. Of course when totally different views were held by two authors on a matter which had to be dealt with in two sections, no serious attempt was made to urge these writers to qualify their statements so as to produce an apparent agreement. It was felt that if this were done the individuality of the author, which forms a characteristic feature of each article as it stands, would thereby be damaged; and further, it was believed that the same question discussed from two different points of view could not fail to be of advantage to the reader. At the same time it is right to state that the places in which a divergence of opinion appears are very few, and taking into account that nine writers have co-operated with the Editor, a remarkable degree of harmony in the treatment of the different sections has been obtained.

The recent introduction of Formalin as a hardening and preserving reagent imposed an especially arduous duty upon those writers who had undertaken the chapters dealing with the thoracic and abdominal viscera. The possibilities for establishing a more accurate topography and of improving our conception of the forms assumed by the viscera under different conditions have by this means been greatly extended; and in preparing the sections which treat of these organs the writers have taken full advantage of the new method. Much, therefore, which appears in this book on the topographical relations of the viscera departs considerably from the older and more conventional descriptions hitherto in vogue.

The arrangement of the matter treated in the following pages is very much the same as that adopted in the various courses of lectures delivered in the schools from which the different sections of the work have emanated. The first chapter is

devoted to the general principles and elementary facts of Embryology. Then follow, in an order best suited for the student, the chapters dealing with the various systems of organs; whilst the last seventy-five pages are used for the purpose of applying the information conveyed in the preceding part of the book to the practice of medicine and surgery. Each chapter is more or less complete in itself, although an effort has been made to weld them all into one consistent whole.

The numerous illustrations which appear in the text are all new in the sense that in no case has an old drawing or an old block been used. Further, the vast majority of the illustrations are new in the sense that they are original. The very few that are not have been taken from monographs dealing with the subjects so illustrated, and in every case the source from which these have been obtained is acknowledged in the text. The drawings for each section were prepared under the personal supervision of its author, and, with the exception of the figures in two chapters, they are the work of Mr. J. T. Murray. This talented artist has devoted much time to the undertaking, and the reader can judge for himself the success which has attended his efforts. The Editor cannot sufficiently express his indebtedness to Mr. Murray for the great technical skill and the patience which he brought to bear upon this extremely trying and difficult work. The chapter on Osteology has been illustrated by Mr. W. C. Stevens; that upon Embryology by the authors themselves; whilst the microscopical drawings in the section on the Brain and Cord were executed by Mr. Wm. Cathie. It is also necessary to mention that the coloured outlines representing the attachments of the muscles on the figures of the bones were mapped in by Professor A. M. Paterson.

The Editor has to thank his former Assistant, Professor A. F. Dixon of Cardiff, for much help in the correction of the proofs.

Trinity College, Dublin,
June 1902.

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The Index is the work of Dr. T. W. P. Lawrence.

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TEXT-BOOK OF ANATOMY.

TEXT-BOOK OF ANATOMY.

INTRODUCTION.

ANATOMY is a comprehensive term, which includes several closely related branches of study. Primarily it is employed to indicate the study of the several parts which build up the body, and the relationship which these present to each other. But during the period of its existence the individual exhibits many structural changes: its structure is not the same at all stages of its life. The ovum or starting-point of every individual is very different from the finished organism as represented by the adult, and the series of changes through which the organism passes until its structure is perfected and full growth is attained constitute the study of **development.** The general term "development" includes not only the various and striking structural changes which occur during the intrauterine life of the individual, to the study of which the term **embryology** is more specially applied, but also many growth processes which occur after birth, such as the later stages in the ossification and growth of the bones, the eruption of the two series of teeth, the adjustment of the vascular system to its new requirements, etc. The actual observation of the processes by which the parts of the body are gradually formed, and of the structural arrangements by means of which a temporary connexion is established between the ovum and the mother, through which an interchange of nutritive and other matters between the two takes place, renders embryology one of the most interesting of all the departments of anatomy. The term **ontogeny** is also used to denote the development of the individual. There is, however, another form of development, slower, but just as certain in its processes, which affects not only the individual, but every member of the animal group collectively to which it belongs. The theory of descent or evolution leads us to believe that between man of the present day and his remote ancestors there is a wide structural gap, which, if the geological record were perfect, would be seen to be completely occupied by long-lost intermediate forms. In the process of evolution, therefore, structural changes have gradually taken place which have modified the entire race. A more or less close or remote blood-relationship links together all the members of the animal kingdom. These evolutionary phases constitute the ancestral history or **phylogeny** of the individual. Ontogeny and phylogeny are intertwined in a remarkable manner, and present certain extraordinary relationships. In other words, the ancestral evolutionary development appears to be so stamped upon an individual that it repeats certain of the phylogenetic stages with more or less clearness during the process of its own individual development. Thus at an early period in the embryology of man we recognise evanescent gill-slits comparable with those of a fish, whilst a study of the development of his heart shows that it passes

through transitory structural conditions in many respects similar to the permanent condition of the heart in certain of the lower animals. It is in connexion with this that the phrase has arisen that every animal in its individual development or ontogeny climbs up its own genealogical tree—a saying which, taking it even in the broadest sense, is only partially true.

The higher conceptions of anatomy, which are obtained by taking a general survey of the structural aspects of the entire animal kingdom, constitute **morphology**. The morphologist investigates the laws of form and structure, and in his generalisations he gives attention to detail only in so far as this is necessary for the proper establishment of his views. The knowledge of anatomy which is required by the student of medicine is different. It is essentially one of detail, and often details important from the practical and utilitarian points of view have little or no morphological value. This want of balance in the interest attached to anatomical facts, according to the aspect from which they are examined, so far from being unfortunate, affords the teacher the means of making the study of anatomy at once fascinating and attractive. Almost every fact which is brought under the notice of the student can be accompanied by a morphological or a practical application. This it is that lightens a study which, presented to the student of medicine in any other way, would be at once dry and tedious.

Certain terms employed in morphology require early and definite explanation. These are homology, serial homology, and homoplasy. The same organ repeated in two different animals is said to present a case of **homology**. But this morphological identity between these two organs must be proved beyond dispute before the homology between them can be allowed. In deciding this identity the great and essential test is that the two organs in question should have a similar developmental origin. Thus the fore-limb of a quadruped is homologous with the upper limb of man; the puny collar-bone of a tiger, the fibrous thread which is the only representative of this bone in the horse, and the strongly marked clavicle of the ape or man, are all, strictly speaking, homologous with each other. Homologous organs in different animals usually present a similar position and a similar structure, but not invariably so. It is not uncommon for a muscle to wander somewhat from its original position, and many cases could be quoted in which parts have become completely transformed in structure, either from disuse or for the purpose of meeting some special demand in the animal economy. In the study of the muscles and ligaments instances of this will be brought under the notice of the reader. Identity or correspondence in the function performed by two organs in two different animals is not taken into consideration in deciding questions of homology. The gills of a fish and the lungs of a higher vertebrate perform very much the same physiological office, and yet they are not homologous. The term **analogy** is often used to express functional correspondence of this kind. Often organs which perform totally different functions are yet perfectly homologous. Thus the wing of a bat or the wing of a bird, both of which are subservient to flight, are homologous with the upper limb of man, the office of which is the different one of prehension.

In the construction of vertebrates and certain other animal groups a series of similar parts are repeated along a longitudinal axis, one after the other. Thus the series of vertebræ which build up the backbone, the series of ribs which gird round either side of the chest, the series of intercostal muscles which fill up the intervals between the ribs, the series of nerves which arise from the brain and spinal cord, are all examples of this. An animal exhibiting such a condition of parts is said to present the **segmental type** of organisation, and in the early stages of development this segmentation is much more strongly marked, and is to be seen in parts which

subsequently lose all trace of such a subdivision. The parts thus repeated are said to be **serially homologous**. But there are other instances of serial homology besides those which are manifestly produced by segmentation. The upper limb is serially homologous with the lower limb: each is composed of parts which, to a large extent, are repeated in the other, and the correct adjustment of this comparison between the several parts of the upper and lower limbs constitutes one of the most difficult and yet interesting problems of morphology.

Homoplasy is a term which has been introduced to express a form of correspondence between organs in different animals which cannot be included under the term homology. Two animal groups, which originally have sprung from the same stem-form, may independently develop a similar structural character which is altogether absent in the ancestor common to both. Thus the common ancestor of man and the carnivora in all probability possessed a smooth brain, and yet the human brain and the carnivore brain are both richly convoluted. Not only this, but certain anatomists seek to reconcile the convolutionary pattern of the one with the convolutionary pattern of the other. What correspondence there is does not, in every instance, constitute a case of homology, because there is not in every case a community of origin. Correspondence of this kind is included under the term "homoplasy." Another example is afforded by the heart of the mammal and that of the bird. In both of these groups the ventricular portion of the heart consists of a right and a left chamber, and yet the ventricular septum in the one is not homologous with the corresponding septum in the other, because the common ancestor from which both have sprung possessed a heart with a single ventricular cavity, and the double-chambered condition has been a subsequent and independent development in the two groups.

Systematic Anatomy.—The human body is composed of a combination of several systems of organs, and the several parts of each system not only present a certain similarity in structure, but also fulfil special functions. Thus we have—

1. The *skeletal system*, composed of the bones and certain cartilaginous and membranous parts associated with them, the study of which is known as **osteology**.

2. The *articulatory system*, which includes the joints or articulations, the study of which is termed **arthrology**.

3. The *muscular system*, comprising the muscles, the study of which constitutes **myology**.

4. The *nervous system*, in which are included the brain, the spinal cord, the spinal and cranial ganglia, the sympathetic ganglia, and the various nerves proceeding from and entering these. The study of these parts is expressed by the term **neurology**. In this system the organs of sense may also be included.

5. The *vascular* and *lymphatic* system, including the heart, blood-vessels, the lymphatic vessels, and the lymphatic glands. **Angeiology** is the term applied to the study of this system.

6. The *respiratory system*, in which we place the lungs, windpipe, and larynx.

7. The *digestive system*, which consists of the alimentary canal and its associated glands, and parts such as the tongue, teeth, liver, pancreas, etc.

8. The *urogenital system*, composed of the urinary organs and the reproductive organs—the latter differing in the two sexes.

The term **splanchnology** denotes the study of the organs included in the respiratory, digestive, and genito-urinary systems.

9. The *integumentary system*, consisting of the skin, nails, hair, etc.

These numerous organs which form the various systems are themselves built up of tissues, the ultimate elements of which can only be studied by the aid of the

microscope. The study of these elements and the manner in which they are grouped together to form the various tissues of the body forms an important branch of anatomy, which is termed **histology**.

The structure of the human body may be studied in two different ways. The several parts may be considered with reference to their relative positions, either as they are met with in the course of an ordinary dissection, or as they are seen on the surface of a section through the body. This is the *topographical method*. On the other hand, the several systems of organs may be treated separately and in sequence. This constitutes the *systematic method*, and it is the plan which is adhered to in this treatise.

Descriptive Terms.—Anatomy is a descriptive science founded on observation, and in order that precision and accuracy may be attained it is absolutely necessary that we should be provided with a series of well-defined descriptive terms. It must be clearly understood that all descriptions are framed on the supposition that the body is in the erect position, with the arms by the side, and the hands held so that

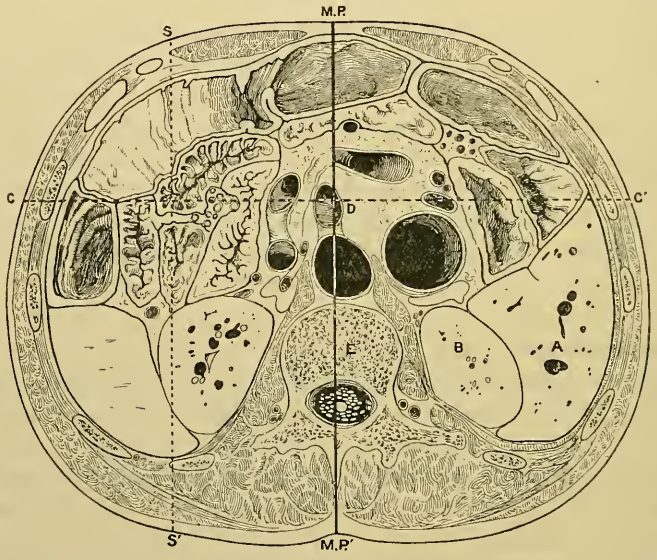


Fig. 1.—Horizontal Section through the Trunk at the Level of the First Lumbar Vertebra.

the palms look forwards and the thumbs outwards. An imaginary plane of section, passing longitudinally through the body so as to divide it accurately into a right and left half, is called the **mesial plane**, Fig. 1 (M.P.). When the right and left halves of the body are studied it will be found that both are to a large extent formed of similar parts. The right and left limbs are alike; the right and left halves of the brain are the same; there are a right and left kidney and a right and left lung, and so on. So far the organs are said to be **symmetrically** arranged. But still a large amount of **asymmetry** may be observed. Thus the chief bulk of the liver lies to the right side of the mesial plane, and the spleen is an organ which belongs wholly to the left half of the body. Indeed, it is well to state that perfect symmetry never does exist. There always will be, and always must be, a certain want of balance between symmetrically placed parts of the body. Thus the right upper limb is, as a rule, constructed upon a heavier and more massive plan than the left, and even in those organs where the symmetry appears most perfect, as for instance the brain and spinal cord, it only requires a closer study to reveal many points of difference between the right and left halves. The line on the front of the body along which the mesial plane reaches the surface is

termed the **anterior median line**; whilst the corresponding line behind is called the **posterior median line.**

It is convenient to employ other terms to indicate other imaginary planes of section through the body. The term **sagittal** is, therefore, used to denote any plane which cuts through the body along a path which is parallel to the mesial plane (S S′); and the term **coronal** or **frontal** is given to any vertical plane which passes through the body in a path which cuts the mesial plane at right angles (C C′). The term **horizontal** as applied to a plane of section requires no explanation.

Any structure which lies nearer to the mesial plane than another is said to be **internal** or **mesial** to it; and any structure placed further from the mesial plane than another is said to lie **external** or **lateral** to it. Thus in Fig. 1, A is external to B; whilst B is internal to A.

The terms **anterior** and **ventral** are synonymous, and are used to indicate a structure (D) which lies nearer to the front or ventral surface of the body than another structure (E) which is placed nearer to the back or dorsal surface of the body, and which is thus said to be **posterior** or **dorsal.** In some respects it would be well to discard the terms "anterior" and "posterior" in favour of "ventral" and "dorsal," seeing that the former are only applicable to man in the erect attitude, and cannot be applied to an animal in the prone or quadrupedal position. They have, however, become so deeply ingrained into the descriptive language of the human anatomist that it would hardly be advisable at the present moment to adopt this course. A similar objection may be raised to the terms **superior** and **inferior**, which are employed to indicate the relative levels at which two structures lie with reference to the upper and lower ends of the body. The equivalent terms of **cephalic** and **preaxial** are, therefore, frequently used in place of "superior," and **caudal** and **postaxial** in place of "inferior."

The terms **proximal** and **distal** should only be applied in the description of the limbs. They denote relative nearness to or distance from the trunk. Thus the hand is distal to the fore-arm, whilst the upper arm or brachium is proximal to the fore-arm.

GENERAL EMBRYOLOGY.

By Alfred H. Young and Arthur Robinson.

Although the tissues and organs of the body when fully formed differ greatly not only in respect of their functional characteristics, but also with regard to their structural features, they are developed from cell elements so similar in appearance at first that they cannot be distinguished from one another. They are all the offspring of parent cells—the female cell or **ovum**, and the male cell or **spermatozoon**. Developmental processes apparently take place in the female cell alone, but they cannot occur unless the essential elements of a sperm or male cell previously unite with it.

Like all animal cells, the ovum is a mass of protoplasm (*cytoplasm*) containing a nucleus. In many cells the cytoplasm or cell body is itself enclosed by an external investing membrane, the cell wall, and such a membrane is present in the ovum. Speaking generally, animal cells are minute structures, those of the human body rarely attaining a diameter of more than about ·083 mm., but they vary somewhat in size, they assume different forms, and they acquire characteristic peculiarities associated with their positions and functions; thus, whilst the majority of the constituent cells of an individual form the various tissues and organs of the body, others are reproductive or germinal cells.

Ova are simply specialised cells modified and adapted for the purpose of reproduction and the continuance of the species. They are enclosed, and partially or entirely matured, in the ovaries, or female generative glands, in the cell-lined spaces known as Graafian follicles.

When an ovum has reached a certain stage of development it is discharged from the ovary, and passing along the oviduct or Fallopian tube it eventually reaches the cavity of the uterus. Though mature and capable of being fertilised it may not be impregnated, in which case it does not remain in the uterus, but is cast out from that organ. If, however, it becomes fertilised, by union with the male germinal element, it is retained in the uterus, and develops into an embryo which possesses all the characteristic features of the species to which it belongs and most of the special peculiarities of its parents.

When the embryo, or the fœtus as it is termed after it has assumed definite form, is capable of independent existence, its intrauterine life terminates, and it is separated from the rest of the ovum and is born. The development of the individual, however, is not complete, nor does it become complete until the new being reaches the adult condition.

The term embryology is sometimes used to include the consideration of all the developmental changes and processes which take place in the ovum from the beginning up to the final adult stage. It is more convenient, however, to restrict its application to the study of those changes which take place during the development and growth of the organism before the fœtus is separated from the rest of the ovum, or, in other words, during its intrauterine existence.

Briefly epitomised, the sequence of changes is as follows:—Impregnation of the mature ovum is followed by segmentation or cleavage. By a series of successive divisions the egg-cell is divided into two, four, eight, and ultimately into a large

number of cells, and so is transformed into a multicellular mass, the morula. The majority of the "segmentation masses" or cells, or blastomeres, as they are termed, are differentiated into tissue elements, but a certain number retain the characters of the original germ-cells and become ova or sperm-cells, which form the "points of departure" of succeeding generations. Every germ-cell is derived, therefore, "by a continuous and unbroken series of cell-divisions" which have extended through the past from the most primitive ancestor, and it forms a point from which, under ordinary circumstances, all future generations will commence. It is in this sense that the changes through which a living being passes in the course of its life "may, in their completest form, be considered as constituting a morphological cycle, beginning with the ovum and ending with the ovum again."

To follow these changes it is necessary that the characters and capabilities of the constructive elements should be clearly understood. The animal cell, which plays an all-important part in the life-history of the individual, and the modified germ-cells must be carefully studied, and as far as possible the exact nature of their constituent parts ascertained.

The phenomena of impregnation and segmentation, and the subsequent developmental processes and morphological changes which result in the formation of the embryo, and, finally, the arrangements for the nutrition and protection of the ovum during its intrauterine existence, will then be considered.

THE ANIMAL CELL.

Cells are the structural units of the body. Each cell has an individual life-history within the tissue or organ to which it belongs, it is produced by a pre-existing cell, it develops and grows, is modified by circumstances, reproduces other cells similar to itself, or it dies.

A cell possesses a body and a nucleus. An external investing membrane or cell wall may or may not be differentiated.

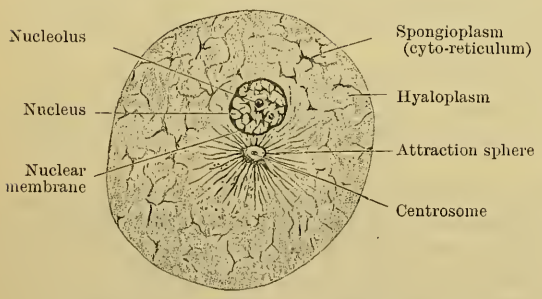


FIG. 2.—DIAGRAM OF AN ANIMAL CELL.

The **cell body** consists of protoplasm—an unstable, highly complex organic substance, the constitution of which is approximately represented by the formula $C_{60}H_{100}N_{16}O_{20}$. It is colourless, semi-fluid, viscous, insoluble in water, capable of osmosis, and it is contractile and irritable. In the living condition it always contains a certain amount of water and various inorganic matters. It is to be observed, however, that there are many varieties of protoplasm, differing somewhat in nature and qualities.

The protoplasm of the cell body is called **cytoplasm.** Under low powers of the microscope it is homogeneous or slightly granular, but with higher magnification, and especially after the application of staining agents, it is possible to distinguish—

(1) A highly refractile, elastic, and extensile network—the **cyto-reticulum** or **spongioplasm**—the meshes of which are filled with

(2) A clear, semi-fluid substance—the **cytolymph** or **hyaloplasm.**

The fibres of the reticulum present some few minute rounded bodies of doubtful nature, which are termed **microsomes.**

The **nucleus** is a spherical vesicle embedded in the cell body. It is surrounded by a distinct nuclear membrane, and usually contains nucleoli.

It consists of modified protoplasm, which is termed **karyoplasm,** the precise relation of which to the cytoplasm is not clear. Structurally it resembles cytoplasm in that it presents a fine reticulum, the fibres of which seem to be continuous with the cyto-reticulum through the nuclear membrane, whilst its meshes are occupied by **nuclear juice.**

The reticulum forms a fine network composed of **linin** fibres (achromatic substance). There is also a coarser network, more readily stainable, consisting of **chromatin**, granular portions of which may also be embedded in the linin. Instead of forming a coarse network the chromatin may be arranged in the form of a convoluted cord, or as a number of separate filaments, and in certain cases it constitutes a series of loops from which secondary branches are projected, the apices of the loops being grouped together at one pole of the nucleus round a clear area known as the "polar field."

The **nuclear membrane** consists of both chromatin and linin.

Nucleoli are of two kinds, true and false. A true nucleolus is a small, refractile particle, of spherical outline, embedded in the reticulum. It stains deeply, and is said to consist of a special modification of the karyoplasm which is called pyrenin. False nucleoli are simply the nodes of the chromatin reticulum.

The nucleus is capable of motion; it has been seen to alter its shape in the living cell, and it undoubtedly plays an active part in the process of cell reproduction.

In addition to the nucleus many cells contain one or more small rounded bodies called **centrosomes.** The centrosomes are modified portions of the protoplasm, and they lie, as a rule, in a modified, clear-looking area of the cytoplasm, which is known as the **attraction sphere.** This is generally situated close to the nucleus, and from its surface a number of fine radiating lines project into the adjacent cytoplasm.

Centrosomes become very evident when reproduction commences, but are not so distinct at other times.

The attraction sphere also becomes more evident when cell-division commences, and the radii which project from it, as well as the contained centrosome, appear to play important parts in the reproductive process.

Reproduction of Cells.—Cell division or reproduction may take place either—

1. By direct division—**amitosis**;
2. By indirect division—**mitosis** or **karyokinesis.**

In the **amitotic or direct form of division** the nucleus, and then the cell body, are equatorially constricted, the constrictions deepen until both are completely divided, and so two daughter cells are produced. Apparently the attraction sphere

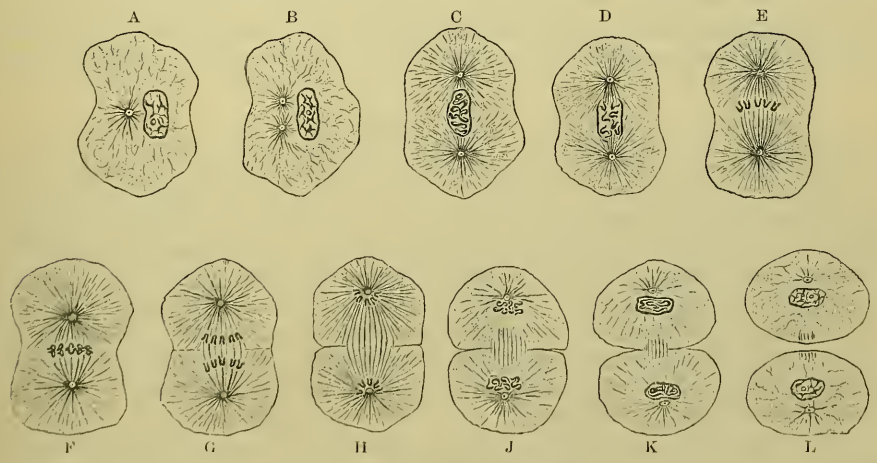


FIG. 3.—CELL DIVISION.

Successive stages of mitosis or karyokinesis (diagrammatic, modified from Hemeguy). A, B, C, D, and E illustrate the phenomena of the prophase; F those of the metaphase; G and H those of the anaphase; J, K, and L those of the telophase.

and centrosome play some part in this process, but whether their influence is initiative or directive is unknown.

Mitosis, the process of indirect division, is by far the most common mode of

cell-division. It is a complex process, and the phenomena observable during its progress are classified into four groups: (1) the *prophase*, (2) the *metaphase*, (3) the *anaphase*, and (4) the *telophase*.

The phenomena of the *prophase* commence with the division of the centrosome and attraction sphere into two parts which travel to opposite poles of the nucleus. At the same time the reticulum of the nucleus disappears, and in its place a convoluted cord of chromatin, the skein or spirem, is formed (Fig. 3, A, B, and C); this is afterwards broken up into a number of segments which may be mere rods, but which more frequently have the form of V-shaped loops (Fig. 3, D). The nucleoli disappear, and some of the filaments which radiate from the newly-formed attraction spheres seem to penetrate the nuclear membrane at the poles of the nucleus. The nuclear membrane subsequently disappears, and the filaments passing from the attraction spheres into the nucleus form two cones, the bases of which meet at the equator of the nucleus, where they fuse together, forming an achromatic spindle which extends between the two attraction spheres (Fig. 3, E).

The loops, or rods, of chromatin are gradually grouped at the equator of the spindle, each rod, or chromosome, being apparently connected with one of the achromatic fibrils; and the prophase is completed.

In the *metaphase* each chromosome is split longitudinally into two halves—daughter chromosomes—which separate from one another; the separation commences at the apex of each V-shaped chromosome, which appears to be attached to an achromatic fibril (Fig. 3, F).

In the *anaphase* the daughter chromosomes pass to the opposite poles of the spindle. It is suggested that this movement is brought about by the contraction of the spindle fibrils, but this is doubtful, though it is noteworthy that in some cases fine achromatic fibrils connecting the separated daughter chromosomes are present (Fig. 3, G and H). Slightly before, or simultaneously with, the completion of the anaphase the cell body is equatorially constricted.

During the *telophase* the constriction deepens and the cell is divided into two daughter cells. Whilst this division is taking place the daughter chromosomes, which are grouped in the neighbourhood of each attraction sphere at opposite ends of the spindle, unite into a convoluted cord, round which a nuclear membrane is formed, whilst the cord is converted into a reticulum, and nucleoli appear (Fig. 3, J, K, L). Therefore when the separation of the daughter cells is completed, at the end of the telophase, each possesses all the characteristic features of the mother cell.

Reproductive Cells.—The germinal elements, the union of which is essential to the formation of a new being, are the ovum or female element, and the spermatozoon or male element.

THE OVUM.

Structurally an ovum presents all the characteristic features of a typical cell. It is peculiar because of the large size of the nucleus and nucleolus and in the possession of two investing membranes, an inner one, the vitelline membrane, which corresponds to the cell wall, and an outer one, the oolemma or zona pellucida. Moreover, the nucleus always occupies an excentric position in the cytoplasm, and the cell body contains nutritive material in the form of yolk granules.

The constituent parts of an ovum have received distinctive names, however; thus the cell body is known as the yolk or vitellus, the nucleus is termed the germinal vesicle, and the true nucleolus is called the germinal spot.

Vitellus or Yolk.—The body of the ovum, consisting as in an ordinary cell of cytoplasm resolvable into reticulum and cytolymph, contains also numerous granules of small but varying size called yolk granules. These are highly refractile, fatty, and albuminoid bodies containing phosphorus and mineral salts; collectively they constitute the **deutoplasm** or **nutritive yolk**, in contradistinction to the **cytoplasm** or **formative yolk**.

Nutritive or food yolk plays an important part in development. In some animals it is the only means of support for the embryo in the early stages of development; in most mammals, on the other hand, the embryo is supplied almost from the first with food not from the egg itself, but directly from the mother

through the placenta. The amount of deutoplasm present in the ova of different animals therefore varies greatly.

Ova in which there is no deutoplasm are spoken of as *alecithal*. Such ova, if they exist, are very rare; most of those usually classed under this head undoubtedly contain a certain amount of deutoplasm granules scattered throughout the cytoplasm, and are better described by the term *oligolecithal*. The size of an ovum is determined by the amount of food yolk present, and all oligolecithal ova are small; the human ovum, which may be taken as a type of the class, is about ·2 mm., or $\frac{1}{125}$th of an inch in diameter.

As the deutoplasm is increased in amount the ovum is increased in size. The deutoplasm also tends to accumulate in certain situations; if the accumulation is at one extremity of the cell the ovum is described as *telolecithal*; such ova are naturally divisible into two areas or poles, a cytoplasmic or formative pole, and a deutoplasmic or nutritive pole.

In *eutelolecithal* ova the deutoplasm almost entirely displaces the cytoplasm from one pole, as in the egg of the fowl, in which the cytoplasm is represented by a disc spread over one pole of a large deutoplasmic mass. In many of the arthropoda the deutoplasm accumulates at the centre of the ovum, which is therefore termed *centrolecithal*.

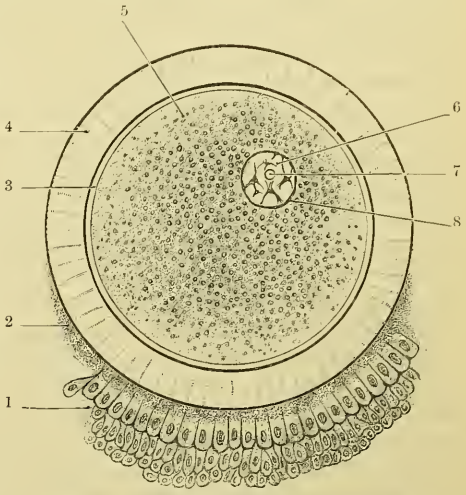


Fig. 4.—The Ovum and its Coverings (Diagrammatic).

The corona radiata, which completely surrounds the ovum, is only represented in the lower part of the figure.

1. Corona radiata.
2. Granular layer.
3. Vitelline membrane.
4. Zona pellucida (oolemma).
5. Vitellus or Yolk.
6. Germinal vesicle (nucleus).
7. Germinal spot (nucleolus).
8. Nuclear membrane.

The **germinal vesicle** or nucleus of the human ovum is about ·05 mm. or $\frac{1}{500}$th of an inch in diameter, *i.e.* $\frac{1}{4}$ the diameter of the whole ovum. It lies excentrically in the yolk, and has the usual characters of a cell nucleus, *i.e.* it possesses a nuclear membrane within which is the karyoplasm, divisible into reticulum or nucleoplasm, and nuclear juice. The nucleoplasm consists of chromatin and achromatic fibres (linin), and the nuclear juice contains one or more spherical and highly refractile true nucleoli or germinal spots; the nodes of the reticulum constitute false nucleoli.

In addition to the nucleus, the vitellus, at certain periods, also contains a structure known as the **vitelline body**, **body of Balbiani**, or accessory nucleus. It is readily seen in young ova lying near the nucleus. It contains one or more centrosomes, and probably represents an attraction sphere.

Vitelline Membrane. — The vitelline membrane is simply the peripheral portion of the vitellus, modified and transformed into a fine structureless envelope which covers the outer surface of the yolk. It is usually closely applied to the inner aspect of the outer membrane, the zona pellucida, and is best seen in the dead ovum and after treatment by reagents. It is therefore thought by some to be merely a condensation of the outer part of the vitellus produced by the action of the reagents. There is evidence, however, to show that it is present in the normal living ovum.

Zona Pellucida or Oolemma.—This membrane is thick, tough, and refractile. It serves as a protective covering for the ovum, and persists for a considerable time after fertilisation, only disappearing when the ovum becomes attached to the uterus. It is perforated by numerous fine canals, which give to the broad clear membrane a finely striated appearance, from which circumstance it has been called the "zona striata." The zona pellucida is not formed by the ovum, but is secreted by the cells of the Graafian follicle in which the ovum lies; it is consequently regarded as a secondary membrane, and is altogether different from the vitelline

membrane. The perforations in the zona serve for the passage of nutritive material to the ovum.

When the ovum leaves the Graafian follicle it is surrounded by several layers of cells, the innermost of which are columnar. They are derived from the cells of the follicle, and collectively constitute the **corona radiata**; the cells gradually diminish in size, and ultimately disappear. Their function is unknown, but between them and the zona pellucida there is a layer of granular matter, probably formed by the cells of the corona radiata, which rapidly swells up when the ovum is liberated from the follicle, and forms a gelatinous elastic layer called **the albumen**; this increases in thickness as the ovum passes along the oviduct, and persists for some time after it enters the uterine cavity. The function of the albumen has not been definitely ascertained; it may act merely as a protective covering against undue pressure, possibly it may be nutritive, whilst in the dog it apparently helps to fix the ovum to the wall of the uterus. It has not been found in all mammalian ova, and it has not been seen round the human ovum; still it may be present, for human ova at the stage when it might be expected to develop have not yet been observed.

Special Characters of the Ovum.—The ovum as it lies in the Graafian follicle presents no obvious structural modifications when compared with an ordinary animal cell, but undoubtedly differs greatly in its capabilities and life history. Unlike an ordinary cell, it has no inherent power of division into two *equal* parts, but before it is capable of fertilisation it twice undergoes *unequal* division during the period of ripening or maturation; again, its history is different from that of ordinary tissue cells, though it corresponds closely with that of the male germinal elements or spermatozoa.

Maturation of the Ovum.—As it lies in the Graafian follicle before maturation commences, the ovum is, strictly speaking, an oocyte of the first order, derived by a process of cell-division and growth from a primitive germinal cell which became embedded in the ovary. The more direct descendants of this primitive germ cell are called **oogonia**, and from them **oocytes of the first order** are developed.

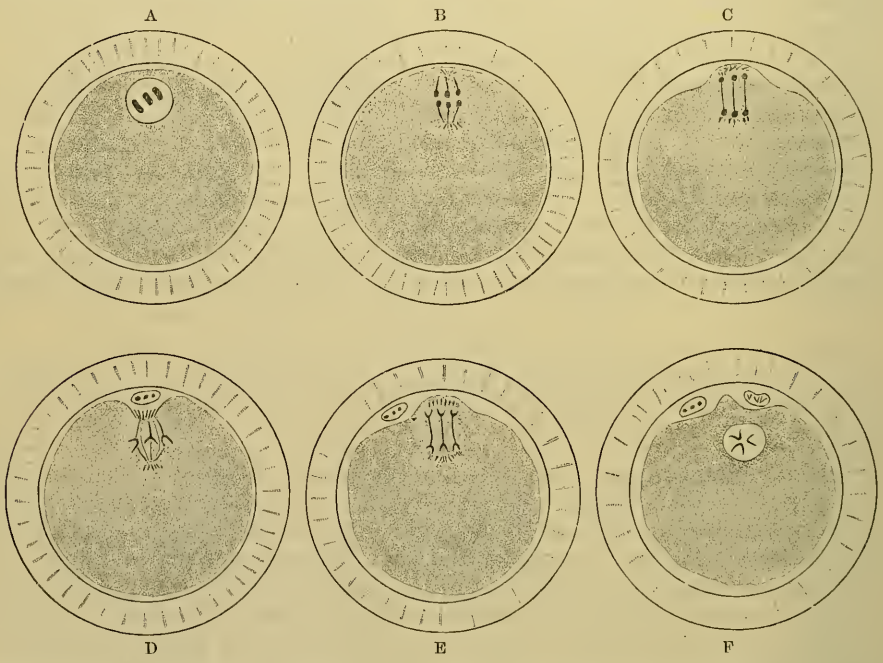


Fig. 5.—The Maturation of the Ovum: Extrusion of the "Polar Bodies" (Diagrammatic).

A, An ovum at the commencement of the process; B, After the formation of the spindle. The chromosomes are gathered at the equator of the spindle. C, One apex of the spindle has projected into a bud on the surface, and half of the divided dyads have passed to each pole; D, The separation of the first polar body; E, The commencement of the second polar body; F, The completion of the second polar body.

The oocyte of the first order is at first small, but as the Graafian follicle in which it lies grows the oocyte also increases in size, and either before or immediately after its extrusion from the follicle it undergoes the changes which constitute maturation or preparation for fertilisation; in other words, it divides twice into unequal parts by a modified process of mitotic division.

It is a well-known fact that all animal cells contain in their nuclei a definite number of chromosomes, the number varying in different groups of animals, but being constant in any given species, and both the primitive germ cells and the oogonia descended from them contain the same number of chromosomes as ordinary tissue cells. But when the oocyte of the first order begins to prepare for the first division during the process of maturation, it is seen that the number of chromosomes it contains is only half that of the ordinary tissue cells. Moreover, the chromosomes are not slender V-shaped loops, but short, thick rods in rings or groups of four granules, and if they are rod-like they do not lie in the prophase with their long axes at an angle with the achromatic spindle, as in ordinary mitosis, but parallel with the filaments of the spindle. During the metaphase the chromosomes do not split longitudinally as in ordinary mitosis, but transversely. This modifica-

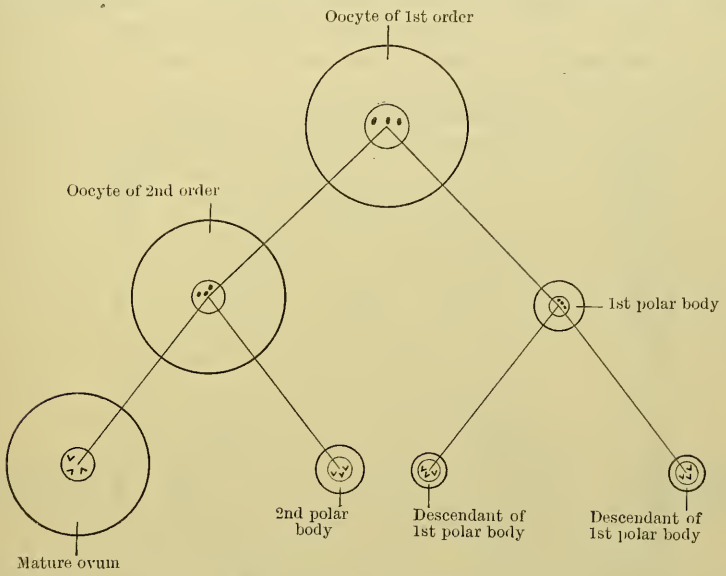


FIG. 6.—DIAGRAM ILLUSTRATING THE MATURATION OF THE OVUM. It must be remembered that in some cases only one polar body is formed, and in others the first polar body does not divide into two parts.

tion of ordinary or *homotype mitosis* is known as *heterotype mitosis*; it takes place not only in oocytes of the first order at the commencement of maturation, but also in the cells of malignant tumours, and its exact signification is not understood. If we imagine that the nuclei of the tissue cells of the animal with which we are dealing contain six chromosomes each, then at the commencement of the first maturation division of the oocyte only three chromosomes will be seen on the spindle which forms. The spindle at its appearance is parallel with one surface of the ovum, but it gradually rotates till it stands at right angles to the surface upon which it impinges, pushing a small part of the cytoplasm before it in the form of a small bud (Fig. 5, B and C). In the anaphase the chromosomes divide transversely, and three half chromosomes pass to the inner end of the spindle and three to the outer end, that is, into the bud-like projection. When the telophase is completed the oocyte of the first order is divided into a small part, the **first polar body**, and a larger part, the **oocyte of the second order**, and each contains three chromosomes (Fig. 5, D). Almost immediately the heterotype division is followed in the oocyte of the second order by a homotype division, no resting stage intervening. A new spindle appears, the three chromosomes radiate from its equator in the usual way, and they divide longitudinally. Three of the daughter

chromosomes pass to the inner end of the spindle and three to the outer, which projects into a second polar bud. Division now occurs, and the oocyte of the second order divides into the **mature ovum** and the **second polar body**, each of which contains three chromosomes in its nucleus (Fig. 5, E and F). Thus at the end of maturation there lie within the zona pellucida the mature ovum and two polar bodies, and the nucleus of the mature ovum, or female pronucleus as it is called, contains half the number of chromosomes which were present in the primitive germ cell.[1]

THE SPERMATOZOON.

Spermatozoa are modified cells produced in the testicles or male generative glands. They are formed from the spermatogonia or sperm mother cells which are derived from the primitive germ cells of the testicle, and which ultimately produce the **spermatocytes of the first order** (Fig. 7), the latter constituting the immediate point of departure in the production of a spermatozoon, and corresponding therefore with the ovum or oocyte of the first order immediately before its maturation commences. The daughter cells of the spermatocytes of the first order are **spermatocytes of the second order**, and their descendants the **spermatids** are the granddaughter cells of the spermatocytes of the first order. The spermatids become closely associated with special sustentacular or nurse cells, and during this association are converted into spermatozoa.

Each spermatid is a cell possessing a cell body, a nucleus, two centrosomes, and a structure known as an idiosome. The latter is believed by some authorities to

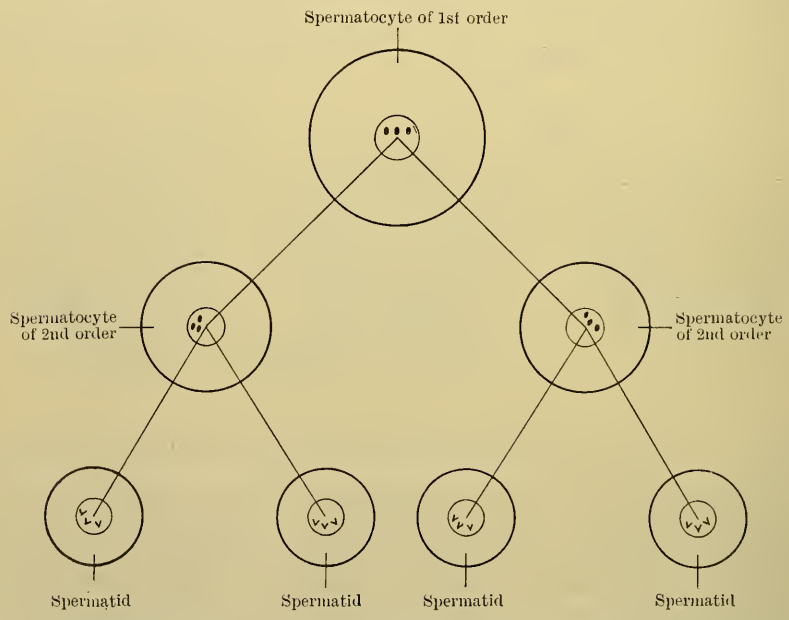


FIG. 7.—DIAGRAM ILLUSTRATING THE PROCESS OF CELL-DIVISION RESULTING IN THE FORMATION OF SPERMATIDS WHICH ARE AFTERWARDS MODIFIED INTO SPERMATOZOA.

represent the attraction sphere, whilst others look upon it as a special modification of the protoplasm only established during the process of mitosis, and distinct from the attraction sphere. However this may be, the nucleus of the spermatid becomes the head of the spermatozoon (Fig. 9). The idiosome forms the head cap, a tail filament grows out from the region of the centrosomes, and the body of the spermatid forms part if not all of the neck, body, tail, and end piece of the spermatozoon. The centrosomes become embedded in the neck, one at its cephalic and the other at its caudal end. The axial filament is closely connected with the posterior centrosome, which has possibly united with the cytoplasm in its formation.

[1] In the mouse, and probably also in some other mammals, only one polar body is formed in many cases.

There is no doubt that the mature ovum and the spermatozoon, so far as their development is concerned, are very similar. Each is derived from a primitive germ cell, which becomes embedded in the generative gland. From the primitive germ cell in the one case oogonia are formed and in the other spermatogonia, and from the oogonia and spermatogonia respectively oocytes and spermatocytes of the first order are derived. The oocyte of the first order divides by heterotype mitosis into an oocyte of the second order and the first polar body, and the spermatocyte of the first order divides, also by heterotype mitosis, into two spermatocytes of the second order. By a second and homotype mitosis the oocyte of the second order divides into a mature ovum and a second polar body, and the spermatocyte of the second order divides into two spermatids. Thus the final result of the division of the spermatocyte of the first order is the formation of four granddaughter cells or spermatids, each of which contains half the number of chromatic particles present in the primitive germ cell, whilst the final result of the division of the oocyte of the first order is the production in some cases of only three granddaughter cells, the mature ovum and two polar bodies, but in many cases the first polar body divides in the homotype manner simultaneously with the division of the oocyte of the second order, and thus the final result of the division of the oocyte is four granddaughter cells, the mature ovum and three polar bodies, each containing half the number of chromosomes present in the primitive germ cell. There are, however, two differences of importance between the male and the female elements. The final result of the division of the female element is one mature ovum immediately capable of fertilisation and further development, and two or three polar bodies which are incapable of further development and which ultimately disappear. On the other hand, the result of the division of the male element is the production of four equal parts, the spermatids, each of which undergoes further modification, and is transformed into a spermatozoon capable of fertilising a mature ovum.

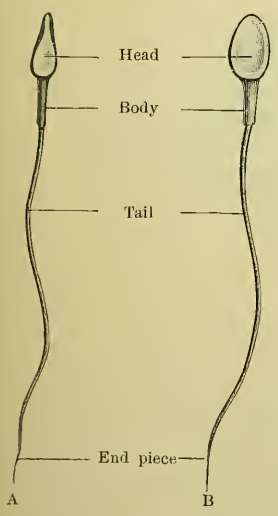


Fig. 8.—Human Spermatozoa (after Retzius).

A, Side view; B, Front view.

A **spermatozoon**, like an ovum, is a nucleated mass of cytoplasm, but it presents striking modifications in structure. It is very small, and possesses a head, a neck, a body, a tail, and an end piece (Fig. 8). In addition it is provided with a head cap which covers more than the anterior half of the head (Fig. 9). This cap is modified over the apex of the head into a sharp cutting edge, by means of which the spermatozoon, driven forward by the movement of the tail, pierces its way through the oolemma of the ovum.

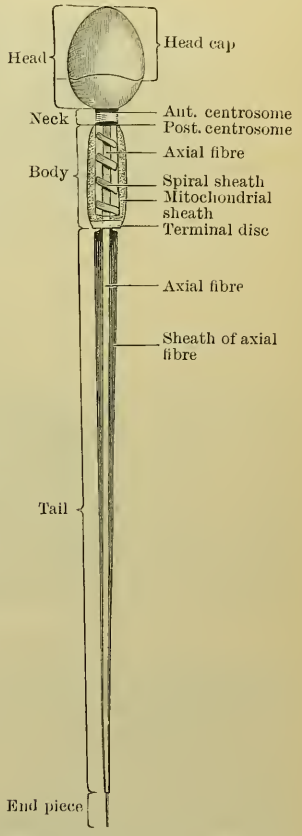


Fig. 9.—Structure of a Human Spermatozoon (after Meeves).

In the short neck are an anterior and a posterior centrosome separated by an intermediate disc, and from the posterior centrosome an axial filament extends through the body and tail, and terminates posteriorly as the end piece. The axial filament is surrounded by a sheath which is thicker in the body than in the tail. Outside the sheath of the axial filament, in the body, is a spiral sheath, and this is enclosed by a sheath of punctiform substance, the mitochondrial sheath, which rests at the lower end of the body on an annulus or terminal disc.

A transverse striation of the head, a spiral filament, a spiral sheath associated with the body and tail, and a terminal spear connected with the head have been described by Bardleben and others, but apparently they do not exist normally as parts of the human spermatozoon.

The head of the spermatozoon is ovoid and laterally compressed, so that when viewed from the side it appears pointed; it is about 4·5 μ long, 2·5 μ broad, and 1·5 μ thick. The body is somewhat longer than the head, and the tail is six times as long as the body, therefore the total length of the spermatozoon is about one-fifth of the diameter of the ovum.

FERTILISATION OF THE OVUM AND THE RESULTS THAT ENSUE.

Fertilisation.—The mature ovum is fertilised by a spermatozoon. The two generative elements meet, and fertilisation takes place as a rule in the upper part of the Fallopian tube. The spermatozoon penetrates the zona pellucida of the ovum, cutting through it by means of the sharp edge of its head cap. At the same time a conical projection, the **cone of attraction**, appears on the surface of the ovum, within the zona pellucida, directly beneath the point at which the

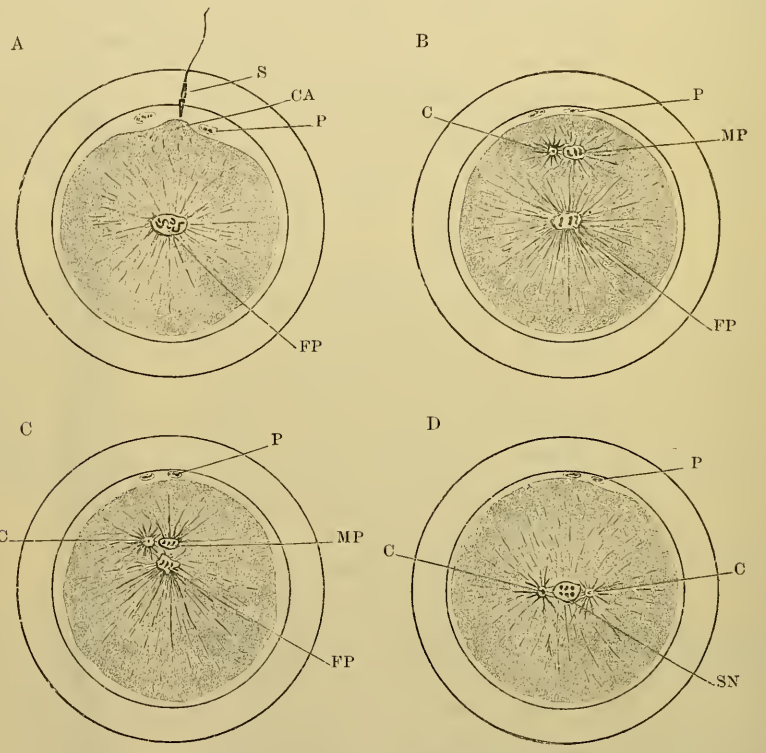


Fig. 10.—Fertilisation of the Ovum (Diagrammatic).

A, The entrance of the spermatozoon and the formation of the cone of attraction; B, The appearance of the centrosome; C, The approachment of the male and female pronuclei; D, The first segmentation nucleus.

C. Centrosome.
CA. Cone of attraction.
FP. Female pronucleus.
MP. Male pronucleus.
P. Polar body.
SN. Segmentation nucleus.

spermatozoon is entering. The head, and probably a portion of the body of the spermatozoon, plunge into the cone of attraction; the remainder of the body and the tail are cast off and disappear. The portion of the spermatozoon which enters the cytoplasm of the ovum is converted into a nucleus, the **male pronucleus**, which is accompanied by its attraction sphere and centrosome. When the male pronucleus is distinctly formed the granules of the cytoplasm in its neighbourhood begin to radiate around it, as if under its influence, and the pronucleus itself travels inwards.

As the male pronucleus approaches the female pronucleus the latter shows

signs of activity, it undergoes changes of form, and moves to meet the male pronucleus. For a time the two pronuclei lie in juxtaposition, and ultimately they fuse together, forming the **first segmentation nucleus.**

The first segmentation nucleus is accompanied by two centrosomes which lie at its opposite poles, and are the products of the male centrosome which divides as the pronuclei fuse.

The **fertilised ovum**, the product of the fusion of the mature ovum and the spermatozoon, contains in its nucleus, the first segmentation nucleus, the same number of chromosomes as the primitive ovum or the sperm-mother cell, but the chromosomes of the segmentation nucleus are derived partly from a male and partly from a female individual.

According to some authorities, both the male and female pronuclei are accompanied by centrosomes, and at the moment of union of the pronuclei each centrosome divides; thus four half-centrosomes are formed, two male and two female. From the four half-centrosomes two new centrosomes are formed by the union of half a male centrosome with half a female centrosome. If this view be correct, each of the two centrosomes which accompany the first segmentation nucleus contains both male and female elements.

Segmentation.—Segmentation is the division of the fertilised ovum (oosperm) into a number of cells. These cells are afterwards arranged in layers—the germinal layers or layers of the blastoderm; ultimately they are differentiated into the tissue elements of the body.

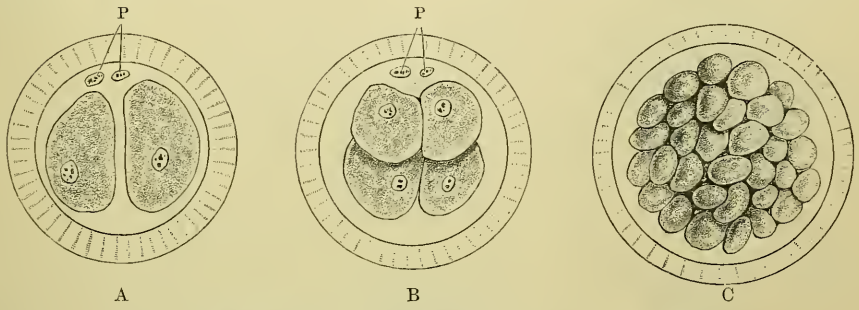


Fig. 11.—Segmentation of the Fertilised Ovum in the Rabbit.

Formation of blastomeres and morula (Diagrammatic).
A, Division into two segments; B, Division into four segments; C, Morula; P, Polar bodies.

All the phenomena of segmentation have not been observed in the human ovum, and it is to be understood that the following description is based chiefly upon the conditions met with in rodents, more especially in the rabbit, an animal well adapted for the study of these phenomena.

After a period of quiescence, which succeeds the fusion of the male and female pronuclei, a period of activity supervenes, during which repeated divisions of the impregnated ovum result in the production of a solid mass of cells called a **morula.** The divisions are mitotic, and all the phenomena associated with mitosis are readily observable in properly prepared specimens.

The planes which separate the several segments of the divided ovum in its various stages are termed the "planes of segmentation," and in some animals the first plane by which the ovum is divided into the first two daughter cells coincides with the future mid-axial or mesial plane of the body, the descendants of the cell lying to the right of it being developed into the right half of the body, and those of the cell to the left into the left half. There is no proof, however, that this occurs in mammals; all that is definitely known is that the first division separates the ovum into two parts of unequal size but of similar colour and structure.

The second plane of segmentation is at right angles to the first, and it separates the two daughter cells into four granddaughter cells, of which, in some cases, two may be larger and two smaller. The subsequent divisions occur irregularly, and they result in the formation of numerous cells (blastomeres) which apparently only differ in size in the rabbit, but which also differ in appearance in many mammals. They are mixed together so irregularly that it is impossible to distinguish the

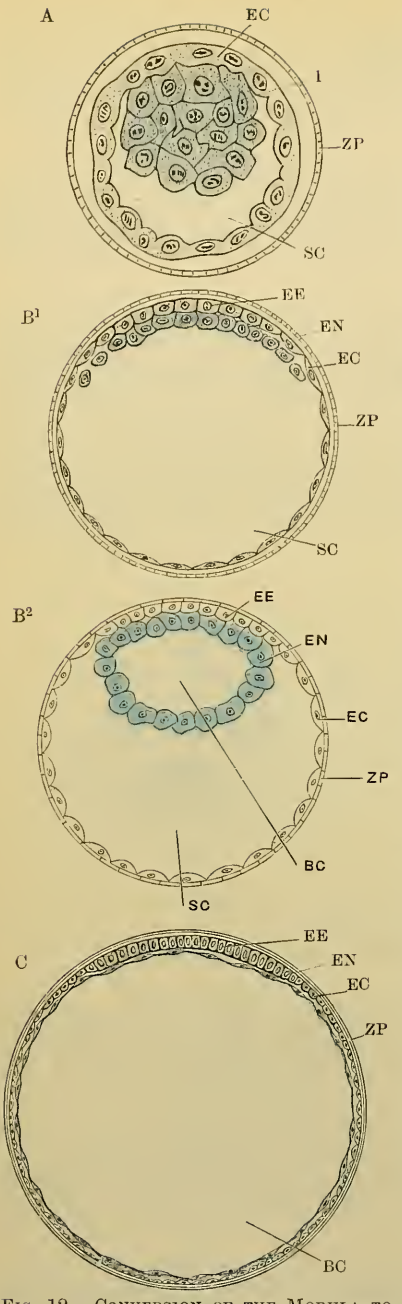


FIG. 12.—CONVERSION OF THE MORULA TO THE BLASTULA.

Formation of blastodermic vesicle and membrane.

A, Appearance of segmentation cavity and attachment of inner cell mass to ectoderm at upper pole of ovum; B^1, Extension and flattening of inner cell mass as it occurs in rabbit and some other mammals; B^2, Extension of entoderm as it occurs in insectivora, monkeys, apes, and man; C, Completion of bilaminar blastodermic vesicle. BC, Blastodermic cavity; EC, Ectoderm; EE, Embryonic ectoderm; EN, Entoderm; I, Inner cell mass; SC, Segmentation cavity; ZP, Zona pellucida.

descendants of one daughter cell from those of the other, and in this, the **morula stage**, there is frequently no indication of any separation of the cells into layers. In the meantime the polar bodies have disappeared.

The next phenomenon of importance is the appearance of a cavity—**the segmentation cavity**—in the morula; the ovum assumes a vesicular character, and is now termed a **blastula.** Simultaneously with the appearance of the cavity the cells of the morula are arranged in two groups—an outer and an inner. The cells of the outer group form a layer, the primitive **ectoderm** or **epiblast**; those of the inner group remain massed together and constitute the **inner cell mass.** The two groups are in contact at one pole of the ovum, and it is in this region that the embryo develops (Fig. 12, A).

In the rabbit and in some other mammals the outer cells of the inner mass at the embryonic pole of the ovum blend with the superjacent primitive ectoderm (Rauber's cells) to form the embryonic ectoderm. This is merely a modification of the more general plan, by which the inner cell mass becomes the inner layer of the now vesicular ovum, but the conversion of the inner mass into the entoderm may take place in two different ways.

(1) In the rabbit and in many other mammals the inner mass gradually flattens out till its cells form a layer at the embryonic pole, and the wall of the vesicular ovum, which is now called a blastodermic vesicle, is partly unilaminar and partly bilaminar (B^1, Fig. 12). Gradually, however, the margins of the entodermal layer extend, and ultimately the cavity of the vesicle is surrounded by two complete layers, ectoderm and entoderm.

In the hedgehog, in monkeys, apes, and the human subject, a cavity appears in the inner cell mass (B^2, Fig. 12), and the cells around it assume a laminar character, constituting the entoderm, which is separated from the ectoderm, except in the embryonic area, by the original cavity of the blastodermic vesicle.

In the case of the hedgehog the cavity in the entoderm expands until the entoderm is forced into contact with the ectoderm, and a condition is attained similar to that met with in the rabbit (C, Fig. 12), but in monkeys, apes, and the human subject the expansion of the entoderm cavity is not so great, and the entoderm does not attain contact with the ectoderm except in the embryonic area.

In amphioxus and many of the invertebrata the results of the segmentation are not quite the same as in mammals, for at a very early period, without the definite formation of a morula mass, the segmentation cells arrange themselves in a layer round a central

cavity and form a complete unilaminar blastoderm. In these cases the bilaminar condition is produced by the invagination of a portion of the wall of the vesicle. The opening at which the invagination occurs is called the **blastopore**. The cavity enclosed by the invaginated cells is the archenteron, or primitive alimentary cavity or gastrula cavity. Except at the blastopore the cavity is surrounded by two layers of cells, an outer the ectoderm, and an inner the entoderm, and the animal at this period of its development is a gastrula. In the mammal the cells which become invaginated in amphioxus to form the entoderm are enclosed in the interior of the morula mass at a very early period of the segmentation, before the vesicular condition is attained, but eventually, as already pointed out, they form a layer inside the ectoderm and they enclose a cavity, the blastodermic cavity, which is homologous with the archenteron or gastrula cavity of the lower forms, but the cavity is closed and the blastopore is not obvious. In amphioxus, however, the blastopore becomes elongated antero-posteriorly, and along the margins a third layer, the mesoderm, grows out between the two primitive layers. In the mammal, on the other hand, after the entoderm and ectoderm are definitely established, a linear streak, called the **primitive streak**, to which further reference will be made, appears on the surface of the ovum; this becomes perforated at its anterior end, and from its margins and mesoderm extends outwards; clearly, therefore, it represents the blastopore of amphioxus though an actual perforation is only present for a short time, and the mammalian ovum at this period may be looked upon as a gastrula.

The ectoderm and entoderm together constitute the blastoderm or blastodermic membrane, which is bilaminar, and the vesicle of which they form the wall is no longer spoken of as the blastula, but as the **blastodermic vesicle.**

Structure of the Ectoderm and Entoderm.—The cells of the ectoderm are at first irregular in size and shape, and their outlines are indistinct; but after a short time the ectoderm cells at one pole of the blastodermic vesicle become cubical or slightly columnar, whilst the remaining cells of the outer layer are flattened and have irregular outlines. The columnar cells form the ectoderm of the embryo, and the flattened cells are utilised in the formation of nutritive and protective structures known as the placenta and fœtal membranes.

The cells of the entoderm are also, at first, very irregular in shape and size, but afterwards, as they are spread out into a layer, they become more or less rounded, and they anastomose together by filamentous processes. At a still later period they are transformed into polygonal plates which appear spindle-shaped in section (Fig. 12).

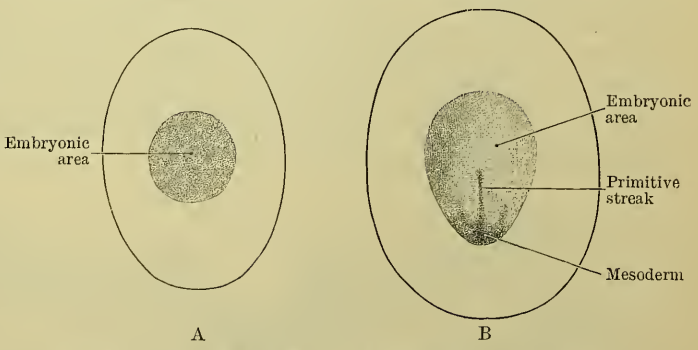


Fig. 13.—Surface View of the Blastodermic Vesicle.

Showing the embryonic area and the commencement of the mesoderm.

A, Before the appearance of the primitive streak—the embryonic area is circular in form and bilaminar throughout; B, After the appearance of the primitive streak. The posterior end of the primitive streak shows a crescentic thickening, which indicates the commencement of the mesoderm or middle layer of the blastodermic membrane.

Embryonic Area. — When the upper pole of the bilaminar blastodermic vesicle is examined in surface view from above, a dark, somewhat opaque circular area is visible; this is known as the embryonic area. It is coextensive with the columnar portion of the ectoderm. Very soon after it appears the embryonic area becomes ovoid; the small end of the ovoid area is posterior, that is, it lies in the region which is afterwards converted into the posterior part of the embryo. At the hinder end of the ovoid area a still darker patch of triangular form is developed; this soon becomes crescentic, and is the first indication of the primitive streak and of the formation of a third blastodermic layer termed the **mesoderm** or **mesoblast.**

The **primitive streak** consists of thickened ectoderm which is seen in transverse sections projecting downwards, and resting upon the entoderm in the form of a ridge.

From the sides and the posterior extremity of the ectodermal ridge a lamina of cells projects outwards, and gradually insinuates itself between the ectoderm and the entoderm over the whole area of the vesicle, except in certain regions to be afterwards described. This lamina is the rudiment of the mesoderm. With the formation of the mesoderm the blastodermic membrane becomes trilaminar.

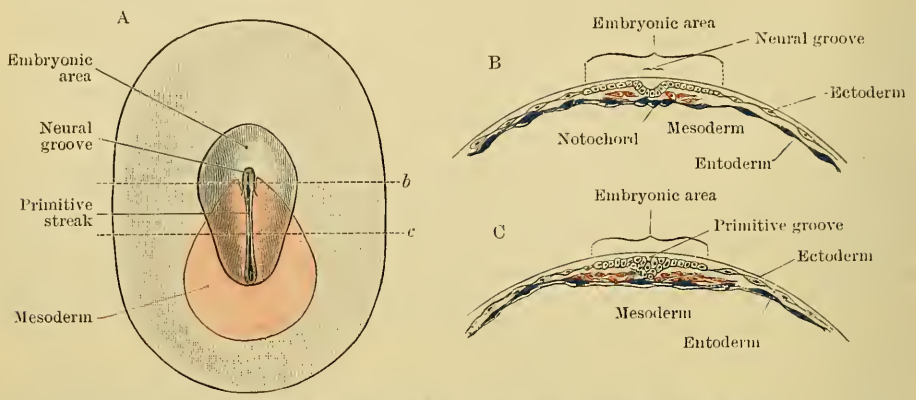


FIG. 14.—THE UPPER POLE OF THE BLASTODERMIC VESICLE.

Showing the embryonic area, the primitive streak with the extension of the mesoderm from its sides and posterior end, and the commencement of the neural groove.

A, Surface view (diagrammatic); B and C, Transverse sections through the blastoderm of the ferret at the stage represented in A and along the lines *b* and *c* respectively.

The majority of the cells of the mesoderm are derived from those of the primitive streak, but it is said that cells from the entoderm also take part in its formation. Young mesodermal cells are round or ovoid, and some give off numerous processes. In later stages they may assume various shapes, and many closely resemble the cells of the ectoderm or those of the entoderm.

As the blastodermic vesicle grows, the embryonic or germinal area becomes pyriform and increases in length, principally in the posterior part of its extent where the primitive streak is situated; at the same time the streak lengthens and

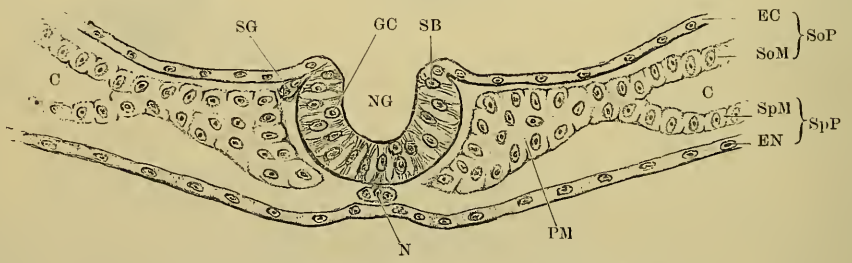


FIG. 15.—TRANSVERSE SECTION OF A FERRET EMBRYO.

Showing neural groove before the separation of the paraxial from the lateral mesoderm.

C. Cœlom.
EC. Ectoderm.
EN. Entoderm.
GC. Germinal cell.
N. Notochord.
NG. Neural groove.
PM. Paraxial mesoderm.
SB. Spongioblast.
SG. Spinal ganglion.
SoM. Somatic mesoderm.
SoP. Somatopleure.
SpM. Splanchnic mesoderm.
SpP. Splanchnopleure.

becomes more linear. For a short time a groove, the **primitive groove**, appears on the surface of the streak. It is deepest in front, where in some mammals, including man, a small transitory perforation is formed, the **neurenteric canal**.

A second broader and shallower groove then appears in the embryonic area immediately in front of the primitive streak; this is the **neural groove**, the rudiment of the nervous system. The neural groove, its bounding folds, and the nervous system subsequently developed from them are formed entirely of ectodermal elements, which at first are continuous with those forming the outer layer of the embryo. The posterior end of the neural groove embraces the anterior end of the primitive streak and groove, and at this period the neurenteric canal forms a communication

between the interior of the ovum and the bottom of the neural groove, which latter afterwards becomes the closed canal of the central nervous system. In some vertebrates the neurenteric canal persists for a considerable period, and upon the development of the alimentary canal it constitutes a communicating channel between it and the cavity of the neural tube.

As the neural groove grows backwards the anterior part of the primitive streak is absorbed, and although the posterior part continues to grow, the primitive streak as a whole diminishes in length; ultimately the greater part of the primitive streak disappears, but a portion is recognisable for a considerable time extending from the base of the tail, a transitory structure in the human embryo, to the ventral wall of the body. This portion forms the posterior boundary of the primitive alimentary canal; it remains bilaminar, and is called the cloacal membrane.

The primitive streak is of great morphological importance; recent researches have shown that from it and the cells in its neighbourhood the greater part of the body of the embryo, with the exception of the anterior part of the head and heart region, is developed. It possibly represents the mouth of a remote (pre-vertebrate) ancestor, the fused lips of which formed the body of a primitive vertebrate animal. The aperture of this mouth is still represented in lower vertebrates by an opening known as the blastopore. The neurenteric canal is the only representative of the opening in the human subject.

The **neural or medullary groove** is bounded laterally by medullary folds which are continuous in front of the groove, but separate behind where they

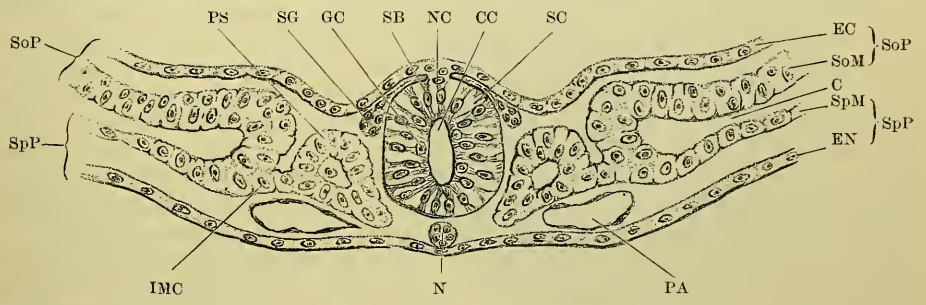


Fig. 16—Transverse Section of Ferret Embryo.

Showing the closure of the neural groove, the formation of the neural crest, the outgrowth of the spinal ganglia, the commencement of the separation of the paraxial mesoderm from the lateral plates, and the differentiation of the intermediate cell mass.

C. Cœlom. GC. Germinal cell. PA. Primitive aorta. SG. Spinal ganglion.
CC. Central canal. IMC. Intermediate cell mass. PS. Mesodermic somite. SoM. Somatic mesoderm.
EC. Ectoderm. N. Notochord. SB. Spongioblast. SoP. Somatopleure.
EN. Entoderm. NC. Neural crest. SC. Spinal cord. SpM. Splanchnic mesoderm.
SpP. Splanchnopleure.

embrace the anterior end of the primitive streak. The neural groove increases in length both in front and behind. The backward increase takes place at the expense of the primitive streak, whilst the anterior increase is due to the rapid growth of the anterior part of the embryonic area; at the same time, not because of, though coincident with, an increase of the mesoderm which has grown beneath them, the medullary folds are gradually elevated, and their apices bending inwards unite together over the neural groove, which is thus converted into a tube or canal —the **neural tube**. The medullary folds unite, in the first place, in the region which afterwards becomes the neck; and subsequently they unite progressively, forwards and backwards.

Along the line of union the neural tube is connected, for a time, with the surface ectoderm by a ridge of cells, the **neural crest**. The crest soon separates from the surface, but it remains connected with the neural tube, and is utilised in the formation of the cranial and spinal nerve ganglia, the sympathetic ganglia, the carotid and coccygeal bodies, and the medullary parts of the suprarenal bodies, whilst the walls of the neural tube are converted into the nervous and sustentacular tissue elements of the whole of the central nervous system (brain and spinal cord).

Before the tube is closed the neural groove is dilated at each end (see Fig. 20). The posterior dilatation is single; it constitutes the rhomboidal sinus, which under ordinary circumstances soon disappears. Anteriorly, numerous dilatations are distinguishable at first. The exact number of these dilatations (neuromeres) is said to be eleven. As the tube closes they resolve themselves into three distinct vesicles termed the **primary cerebral vesicles.** These constitute the rudiments of the fore- mid- and hind-brains, and their respective ventricular cavities. The remainder of the cavity of the tube becomes the central canal of the spinal cord.

After the separation of the neural crest from the surface the mesoderm completely surrounds the whole of the neural tube, and from it are formed the membranes of the brain and spinal cord and their skeletal environments.

The ectodermal cells which form the wall of the primitive neural tube are ill-defined, but they soon differentiate into two sets, **spongioblasts** and **germinal cells.** The spongioblasts are the more numerous, they are columnar in form, and all extend from an internal limiting membrane which is developed round the periphery of the central canal to an external limiting membrane which forms the outer limit of the neural tube. There is frequently considerable difficulty in recognising their columnar character, even in the early stages, partly because their nuclei do not all lie at the same level, and partly because they are so closely opposed. The spongioblasts are converted into the sustentacular tissue, or **myelospongium**, of the brain and spinal cord, but all do not undergo precisely the same transformations. The inner portions of those spongioblasts whose nuclei lie near the central canal retain a columnar form, and cilia grow from their free surfaces into the lumen of the canal; in other words, they are converted into the ciliated epithelium of the central canal, but the outer portions of the same cells are transformed into fibrillar processes which terminate externally by fusing with the external limiting membrane. The remaining spongioblasts entirely lose their columnar form, they become much branched, and their branches interlace with the fibrillar processes of the ciliated epithelial cells, and with similar branches of neighbouring cells, forming the reticular sustentacular tissue or myelospongium; the external limiting membrane is produced by the close interweaving of the peripheral myelospongial fibrils.

The germinal cells are spherical in outline, and contain clear protoplasm and darkly-staining nuclei. They lie between the inner ends of the spongioblasts close to the central canal where, at the fourth or fifth week, they form an irregular layer, and it is believed that they very soon give rise to a new generation of cells, the **neuroblasts,** or young nerve-cells—at all events neuroblasts appear as the germinal cells disappear. Each neuroblast rapidly becomes pyriform by the outgrowth of an **axial process** or **axon,** which projects from its outer end towards the periphery of the tube.

Shortly after their formation the neuroblasts migrate outwards, and ultimately those of the cord are arranged in longer or shorter columns in the myelospongium, whilst those of the brain are grouped together in definite areas to form the cerebral nuclei.

Each neuroblast as it develops gives off many processes, which vary in length and thickness. The first formed of these is the axial process or axon already referred to. It carries impulses from the cell, gives off lateral branches, and terminates either in association with a special end-organ or by ramifying amidst other nerve-processes or round a nerve-cell of the central or peripheral nervous system. The remaining processes of the neuroblast are called **dendrites** or protoplasmic processes. They are usually shorter and more branched than the axon, and they carry impulses to the cell. The whole system of cell body, axon, and dendrites into which a neuroblast develops is termed a **neuron.**

Every neuron is probably a separate and distinct entity. Its processes neither anastomose together nor with the processes of other neurons. They lie, however, in close contiguity with either the body or processes of other neurons, or with special end-organs, and it is possible for impulses to pass from one neuron to another although there is no structural continuity between them.

Extension of the Mesoderm and Division of the Blastodermic Membrane into Areas.—It has already been pointed out that when the primitive streak first

appears it consists of a thickened ridge of ectoderm situated in the posterior part of the embryonic area and resting upon the entoderm. The anterior end of the ridge soon fuses with the entoderm beneath it, and from its sides and posterior extremity a lamelliform outgrowth, the mesoderm, is projected between the ectoderm and entoderm. At its commencement the mesoderm is an outgrowth from the primitive streak, but during its subsequent extension it is probably added to by cells proliferated from the entoderm.

As it extends the mesoderm forms a semilunar sheet of cells, the concavity of the semilune being turned forwards, whilst the convexity is gradually projected beyond the margins of the embryonic area. The cornua of the semilunar sheet grow forwards on either side of, and at some little distance from the middle line, immediately beneath the medullary folds. Each cornu on reaching the anterior end of the embryonic area bifurcates, and the resulting processes unite with their fellows of the opposite side.

At the same time the mesoderm grows from its convex margin, and extends over the rest of the ovum as a continuous sheet. But even when the extension is completed, in the majority of mammals, three areas on the upper aspect of the ovum remain devoid of mesoderm, and consist only of ectoderm and entoderm.

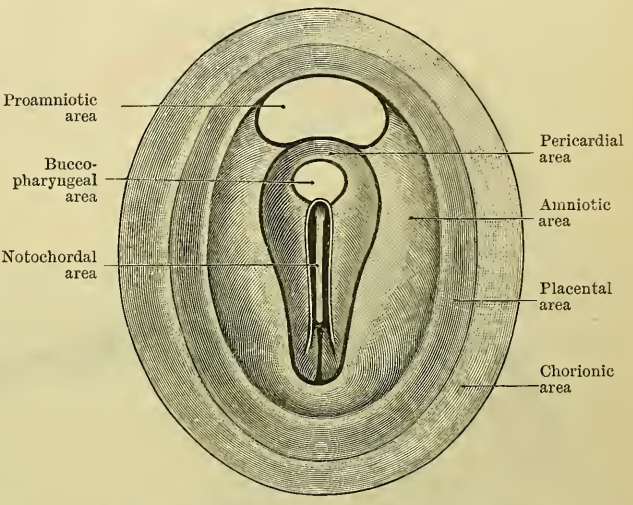


Fig. 17.—Surface Areas of the Blastoderm.

The largest of these areas lies directly in front of the embryonic region. In many mammals it is folded upwards and backwards in front of the head of the embryo, when this becomes distinguishable, and it takes part in the formation of one of the protecting fœtal membranes, viz. the amnion; it is therefore called the **proamnion**, and the area from which it is developed constitutes the **proamniotic area**. Probably it is not present in the human blastoderm, or if it exists it is very transitory.

The second of the areas into which the mesoderm does not extend lies in the embryonic region. It is separated from the proamniotic area by a bar of mesoderm in which the pericardial cavity afterwards appears. The anterior part of this second area is situated in front of the neural groove, and as, at a later period, it forms a septum between the primitive mouth and the pharynx, it may be termed the **bucco-pharyngeal area**. The posterior part of the area forms the floor of the medullary groove, and as the notochord is formed from its entodermal layer we have named it the **notochordal area.**

The third area corresponds to the posterior part of the primitive streak. It extends from the base of the tail towards the umbilicus, forming the **cloacal membrane**, which itself forms the posterior boundary of the primitive alimentary canal. It is eventually perforated by the genito-urinary and anal apertures.

Except in the areas just described, the blastodermic membrane is trilaminar, and at an early period it is possible to distinguish the regions in which the heart and pericardium, the amnion, and the placental and non-placental parts of the chorion are subsequently developed. These regions form fairly well-defined areas, to the relative positions of which reference may now be made.

The anterior part of the embryonic area in front of the bucco-pharyngeal area is the region in which the pericardium and heart are developed, and it may therefore be termed the **pericardial area.**

The blastodermic membrane immediately surrounding the embryonic area,

including the proamniotic part in those animals in which it exists, is the **amniotic area**, and this is bounded externally by a band of elevated and thickened ectoderm which indicates the **placental area**. The latter, together with the blastoderm over the rest of the ovum, forms the **chorionic area**, which is separable, therefore, into placental and non-placental portions.

These areas are further referred to in the description of the folding off of the embryo and the formation of the fœtal membranes and placenta.

Formation of the Notochord.—The notochord is the primitive skeletal axis of the embryo. When differentiated it forms a rod which intervenes between the ectodermal neural tube and the entoderm of the primitive alimentary canal. It is developed from the entoderm beneath the neural groove in the notochordal area. A linear strip of entoderm thickens and then separates as a solid rod of cells, the continuity of the entodermal layer being restored beneath it. When it is completed the notochord extends from a point immediately behind the primitive fore-brain, and

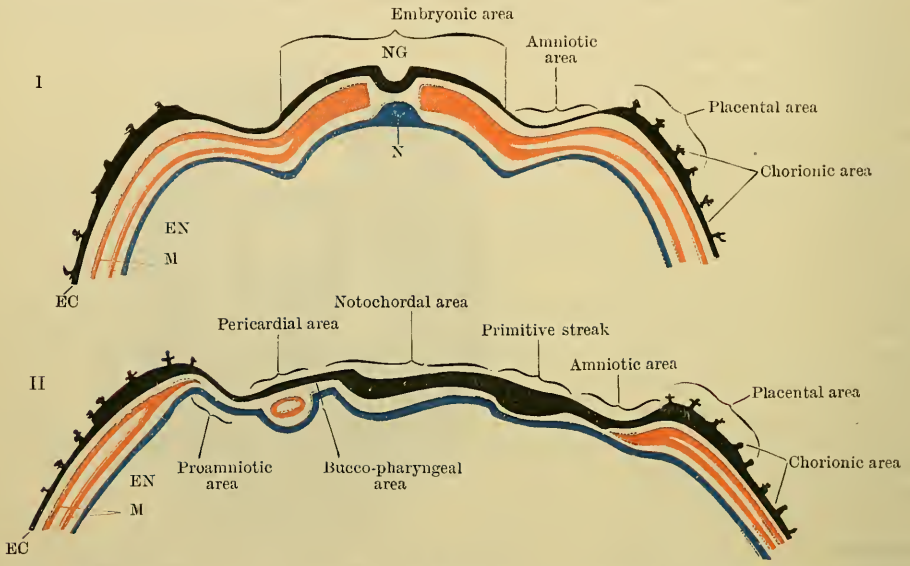


FIG. 18.—SECTIONS SHOWING THE DIFFERENT AREAS OF THE BLASTODERMIC VESICLE (Diagrammatic).

I. Transverse section ; II. Longitudinal section.

EC. Ectoderm. M. Mesoderm. N. Notochordal thickening.
EN. Entoderm. NG. Neural groove.

beneath the anterior end of the mid-brain, to the anterior end of the primitive streak, and in later stages, as the skeleton is formed, the notochord can be traced from the post-sphenoid section of the base of the skull, which is situated beneath the mid-brain, to the tip of the coccyx.

The separation of the notochord from the entoderm commences in the cervical region, and extends forwards and backwards. The anterior extremity is the last part to be detached, the separation occurring shortly after the perforation and disappearance of the bucco-pharyngeal membrane.

The cellular notochord develops a cuticular sheath ; it is subsequently surrounded by mesoderm which separates it both from the neural tube and the entoderm, and which is ultimately transformed into the vertebræ and their ligaments, the intervertebral discs, the basi-sphenoid and basi-occipital parts of the skull, and the membranes of the brain and cord.

As the surrounding mesoderm is differentiated the notochord becomes nodulated ; the thickened portions are situated in the regions of the intervertebral discs, and the intermediate constricted portions in the regions of the vertebral bodies. The vertebral portions gradually disappear, and the intervertebral parts are converted into a kind of mucoid tissue, the pulp of the intervertebral discs.

Formation of the Cœlom.—In all animals in which the entoderm and ectoderm

lie in close relation with each other over the whole surface of the ovum, the

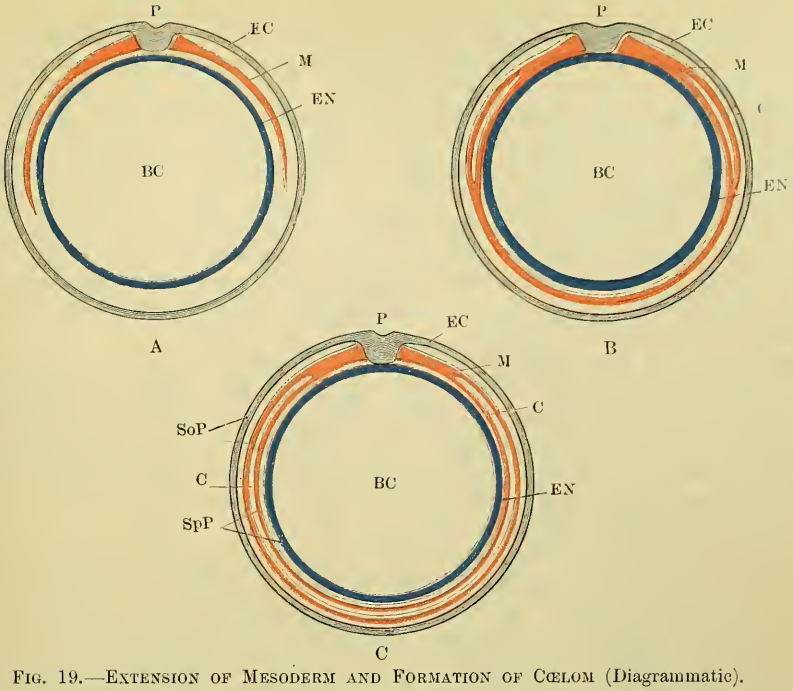


Fig. 19.—Extension of Mesoderm and Formation of Cœlom (Diagrammatic).

A. Mesoderm spreading from the sides of the ectodermal primitive streak, and extending between the ectoderm and entoderm. B. Further extension of the mesoderm and appearance of cœlomic cleft-like spaces. C. Complete delamination of the mesoderm and formation of cœlom.

BC. Blastodermic cavity. C. Cœlom. EC. Ectoderm. EN. Entoderm. M. Mesoderm. P. Primitive Streak. SoP. Somatopleure. SpP. Splanchnopleure.

mesoderm as it extends from the primitive streak forms a single layer, and where this exists the blastoderm is trilaminar, but in monkeys, apes, and the human subject, as the ectoderm and entoderm are separated from each other by the segmentation cavity (Fig. 12, B^2), the mesoderm almost from its commencement extends in two layers, one the splanchnic on the entoderm, and the other the somatic on the inner surface of the ectoderm. In other mammals before the extending mesoderm entirely separates the ectoderm from the entoderm, a cavity is formed in it by the union of a series of cleft-like spaces which appear near the margin of the embryonic area and rapidly fuse together, forming the cœlom or body cavity. Thus in the majority of mammals the cœlom is formed by the cleavage of the mesoderm, but in the higher forms it represents the segmentation cavity which has become surrounded by two extending layers of mesoderm. In those animals

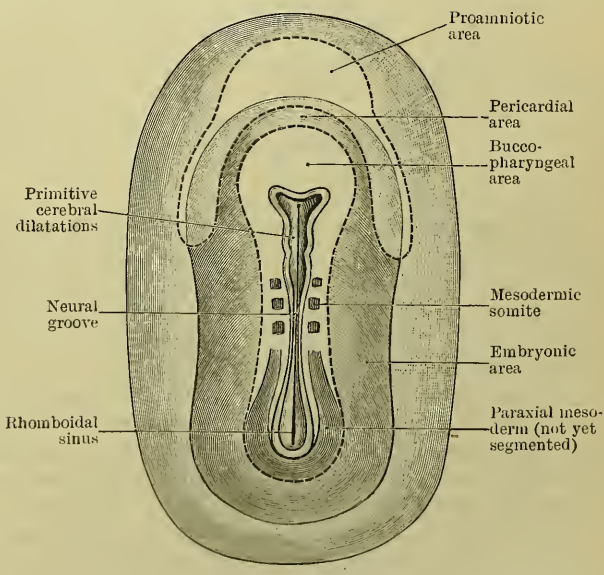


Fig. 20.—Surface View of an Early Embryo (Diagrammatic).

Showing the neural groove, dilated in the head region but still unclosed, and the first protovertebral somites. The margins of the cœlomic space are indicated by dotted lines.

in which it appears by cleavage of the mesoderm, it extends towards both poles of the ovum, but in the higher forms only towards the embryonic pole, and in both groups its extension in the embryonic area is arrested before it quite reaches the side of the notochord and the mesial plane of the primitive streak. It extends across the pericardial area, however, and forms the rudiment of the pericardial cavity, which appears as a transverse tubular passage continuous on each side with the general body cavity. The outer or parietal layer of the mesoderm becomes more or less closely attached to the ectoderm, and with it forms the **somatopleure**, whilst the inner or visceral layer is similarly associated with the entoderm to form the **splanchnopleure.**

When the cœlom is fully formed the blastoderm contains two cavities, one, the cœlom or body cavity, situated between the two layers of the mesoderm, and the other the cavity of the blastodermic vesicle, usually called the vitelline cavity, which lies inside the entoderm.

Mesodermic or Protovertebral Somites.—During the formation of the cœlom the undivided mesoderm at each side of the notochord thickens, principally by a dorsal upgrowth which is coincident with the uprising of the ectodermal medullary folds which bound the neural groove. There are thus formed two thickened bars of mesodermal tissue, one on each side of the neural tube, and they together constitute the **paraxial mesoderm** (Fig. 15); the more laterally situated portions of the mesoderm are known as the **lateral plates.**

The paraxial mesoderm is soon divided, except in the head region, by a number of transverse clefts into a series of cubical masses termed the **mesodermic somites.** These are at first partially, and afterwards more completely separated from the lateral plates by longitudinal grooves. After the longitudinal grooves are formed, the mesodermic somites of each side are connected with the lateral mesoderm by a somewhat contracted strand of cells, the **intermediate cell mass** (Fig. 16). This strand is represented in lower vertebrates by a series of separate cords of cells, the stalks of the somites, each somite possessing one stalk.

The separation of the paraxial mesoderm from the lateral plates and the segmentation of the former into somites extends forwards to the region of the hind brain, where the first protovertebral somite is formed. In front of this the mesoderm, in mammals at least, does not become segmented.

The cavity of the cœlom may extend into the paraxial mesoderm before it is segmented into protovertebral somites, or it may stop just outside the limits of the paraxial mesoderm. In the former case each somite, when separated from the lateral plate, contains a cavity, and the intermediate cell mass is also hollow for a time. In the latter case the protovertebral somites and the intermediate cell masses are solid; at a later period, however, a cavity which contains a few spherical cells appears temporarily in each somite.

Folding Off of the Embryo from the Blastodermic Vesicle.—Although so many rudiments of the embryo become distinguishable at an early period in its development (the embryonic area, the primitive streak and groove, the neural groove, the notochord, and the protovertebral somites), the body of the embryo does not assume its characteristic form until it becomes raised and folded off from the general surface of the blastodermic vesicle.

The main cause of the folding off of the embryo from the surface of the vesicle is the more rapid growth of the embryonic area as contrasted with the slower growth and expansion of the remainder of the wall of the vesicle; and the moulding of the increasing embryonic area into the form of the embryo is due to differences in the rate of growth of the various parts of the area itself.

The manner in which the area is folded, and the changes in the relative positions of its various parts which necessarily result, will be easily understood by reference to Figs. 21 and 27.

The embryonic area at an early period increases rapidly, especially in length. Its margins, however, appear to remain comparatively fixed, and hence as the area increases it must fold upon itself. It becomes more convex externally, and is raised slightly above the general surface, but at the same time it apparently sinks into the interior of the ovum, and the amnion folds close over it.

The antero-posterior growth is greater than the lateral; consequently the folding of the embryonic area is most marked in front and behind. Anterior and posterior, or cephalic and caudal folds are formed, which indicate the head and tail extremities of the embryo. Similarly, lateral folds define the lateral limits of the body.

When the body of the embryo thus becomes folded off it contains a portion of the blastodermic cavity and of the cœlom; the former is the primitive alimentary canal, and the latter is the rudiment of the pericardial, pleural, and peritoneal cavities.

The communication between the pleuro-peritoneal and the extra-embryonic

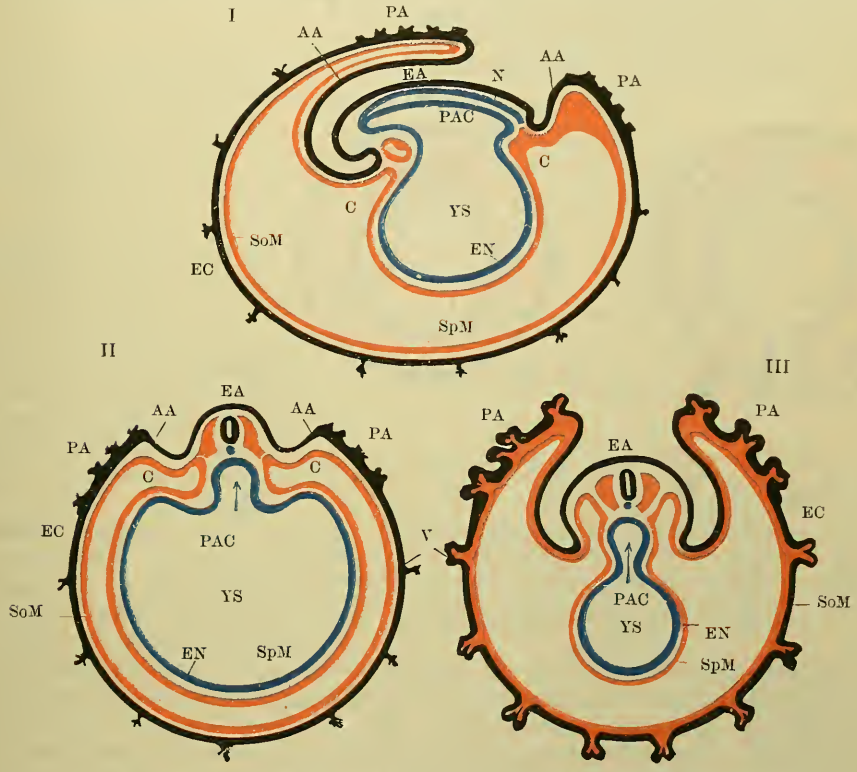


FIG. 21.—EARLY STAGES IN THE FOLDING OFF OF THE EMBRYO (Diagrammatic).

I. Longitudinal section of a developing ovum. The folding off of the embryo has commenced, and the head fold, bending down in front, has invaginated the amniotic area. The tail fold is partly formed, and the primitive alimentary canal, closed in front, communicates freely with the yolk-sac by a wide umbilical aperture.

II. Transverse section of a developing ovum showing the commencement of the "folding off." The thickened embryonic area is convex externally, and it already appears to sink below the surface of the ovum.

III. Transverse section showing the "folding off" more advanced. The changes seen in II. are more marked, and by apparent constriction at the junction of the embryonic area with the rest of the blastodermic vesicle the embryo is still further nipped off, and distinct lateral folds are formed.

The division of the cavity of the blastodermic vesicle into that of the primitive alimentary canal and that of the yolk-sac is shown in all the figures.

The amniotic area, directed upwards and inwards in II., forms with the placental area the amniotic fold, and in III. the amniotic folds of opposite sides are approaching one another over the back of the embryo to enclose the cavity of the amnion. The relative positions of the different areas of the blastoderm are correspondingly modified.

AA.	Amnion fold.	EC.	Ectoderm.	PA.	Placental area.	SpM.	Splanchnic mesoderm.
C.	Cœlom.	EN.	Entoderm.	PAC.	Primitive alimentary canal.	YS.	Yolk-sac.
EA.	Embryonic area.	N.	Notochord.	SoM.	Somatic mesoderm.	V.	Villi.

portion of the cœlom is obviously bounded by the margins of the embryonic area, which constitutes the limits of the umbilical orifice.

The margins of the embryonic area retain approximately their original positions, and in its further growth the embryo extends beyond them in all directions.

THE EMBRYO.

The embryo, now easily distinguishable from the rest of the ovum, is already sufficiently developed to give some indication of the general plan of its organisation, and of the ultimate relation and fate of the three layers of the blastoderm which enter into its constitution. There are as yet no limbs, but the general contour of the head and body are defined. It possesses a notochord, afterwards replaced by the permanent vertebral column, which constitutes a longitudinal central axis. On the dorsal aspect of the notochord the neural groove is closing to form the neural canal, or primitive cerebro-spinal nervous system, whilst on its ventral side a portion of the blastodermic cavity is being included as a primitive tubular alimentary canal, which freely communicates with the remainder of the blastodermic cavity now called the cavity of the yolk-sac.

The formation of the mesodermic somites has commenced, and this is the first indication of that segmentation which is such a characteristic feature in the structure of the vertebrate body.

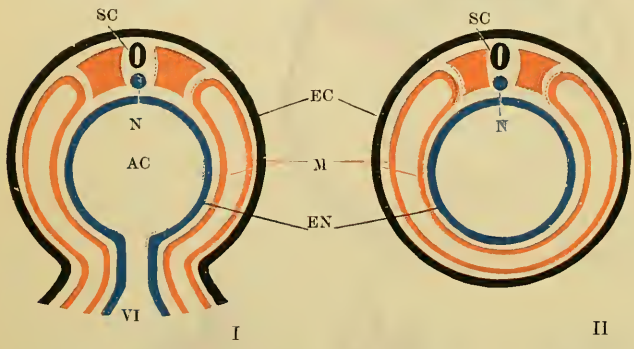


FIG. 22.—THE RELATIVE POSITIONS OF THE BLASTODERMIC LAYERS IN THE BODY OF THE EMBRYO WHEN THE "FOLDING OFF" IS COMPLETED (Diagrammatic).

I. Transverse section through the umbilical aperture.
II. Similar section in front of or behind the umbilicus.

AC. Alimentary canal. EN. Entoderm. N. Notochord.
EC. Ectoderm. M. Mesoderm. SC. Spinal cord.
VI. Vitello-intestinal duct and umbilical aperture.

The general relations of the three layers of the blastoderm remain unaltered. Thus, externally, there is a layer of ectoderm forming the surface of the body; internally, a layer of entoderm lining the primitive alimentary canal; and between them is the mesoderm enclosing the cœlom.

The **surface ectoderm** forms the epithelial elements[1] of the skin and its appendages, and of the glands which open on it. Thus the hairs and hair-follicles, the nails, the enamel of the teeth, the epithelium of the sebaceous glands, of the sweat glands, and of the mammary glands are all ectodermal. The epithelium of the conjunctivæ and of the lachrymal glands is also derived from ectoderm. The roof of the mouth, the inner surfaces of the cheeks, the nasal passages and their associated cavities, together with the adjacent part of the pharynx and the anterior lobe of the pituitary body, as well as the external auditory canal and the outer layer of the tympanic membrane, are all developed from the surface, and their epithelium, with that of their glands, is ectodermal in origin. The epithelium of the sense organs, except that of taste (the tongue), is derived from ectoderm; the auditory and olfactory epithelial elements, and those of the lens and cornea, are from surface ectoderm; whilst the epithelial elements of the retina are from neural ectoderm.

The **neural ectoderm** is removed from the surface to form the neural tube and neural crest, from which the cells and fibres of the whole of the nervous system,[2]

[1] The term "Epithelium" is applied to tissues consisting of cells which are united with one another by means of a small amount of intercellular substance.

The cells constituting epithelium are always arranged in one or more layers; they cover free surfaces and line the various cavities of the body, including the vascular and lymphatic systems; they also form the active elements in secretory glands and line their ducts. Epithelium is always non-vascular, and the cells receive their nourishment from blood-vessels which are in their vicinity. Epithelial cells are modified in accordance with the particular functions they are called upon to serve, and they present many variations in shape, size, and structure, *e.g.* the neuro-epithelial cells of the central nervous system and of the peripheral sense organs differ considerably from the more ordinary epithelial type; but they are simply more specialised, and therefore more modified.

[2] It seems possible that this statement may, before long, require modification, for evidence is being brought forward to show that some portions of the system are developed from peripherally situated ectodermal cells

both central and peripheral, and the sustentacular tissue of the brain and spinal

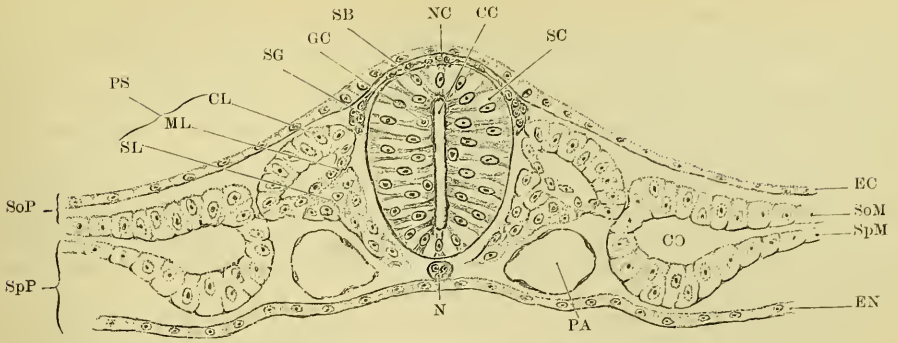


FIG. 23.—TRANSVERSE SECTION OF A FERRET EMBRYO,

Showing further differentiation of the mesoderm.

CC. Central canal.
CL. Cutaneous lamella of protovertebral somite.
CO. Cœlom.
EC. Ectoderm.
EN. Entoderm.
GC. Germinal cell.
ML. Muscular layer of mesodermic somite.
N. Notochord.
NC. Neural crest.
PA. Primitive aorta.
PS. Mesodermic somite.
SB. Spongioblast.
SpP. Splanchnopleure.
SC. Spinal cord.
SG. Spinal ganglion.
SL. Scleratogenous layer of protovertebral somite.
SoM. Somatic mesoderm.
SoP. Somatopleure.
SpM. Splanchnic mesoderm.

cord, are developed. The neural ectoderm also furnishes the epithelial elements of the retinæ, the pineal gland, and of the posterior lobe of the pituitary body. It forms a large part of the vitreous humour of the eye, and contributes to the formation of the carotid, coccygeal and suprarenal bodies.

The **entoderm** lines the alimentary canal and the spaces and glands which open into it, except the upper parts of the mouth and pharynx and the terminal portion of the rectum; thus the epithelium of the Eustachian tube and tympanic cavity, the trachea, the bronchi, the air-vesicles of the lungs, the gall-bladder, the urinary bladder, and part of the urethra is entodermal. It forms the epithelial constituents of the taste buds or organs of taste, the liver and the pancreas, the

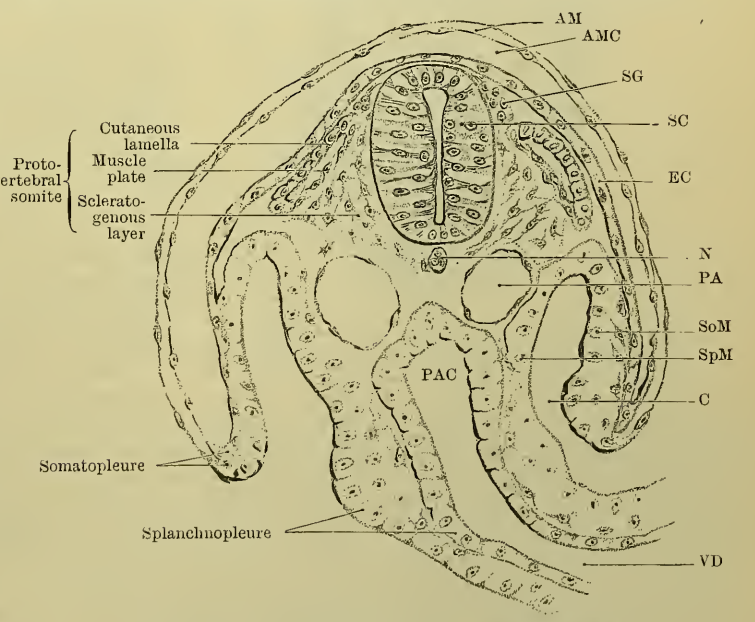


FIG. 24.—FURTHER DIFFERENTIATION OF THE MESODERM.

Transverse section of a rat embryo, showing the transformation of the cells of the scleratogenous layer of a protovertebral somite and their extension round the notochord and spinal cord.

AM. Amnion.
AMC. Amnion cavity.
C. Cœlom.
E.C. Ectoderm.
N. Notochord.
PA. Primitive aorta.
PAC. Primitive alimentary canal.
VD. Vitello-intestinal duct.
SC. Spinal cord.
SG. Spinal ganglion.
SoM. Somatic mesoderm.
SpM. Splanchnic mesoderm.

epithelium lining the vesicles of the thyroid body and the cell nests of the thymus gland.

From the **mesoderm** all the remaining structures which intervene between the surface ectoderm and the entodermal lining of the primitive alimentary tube are formed.

Mesodermic Somites and the Lateral Plates.—Each mesodermal somite consists of numerous cells arranged radially round a central cavity—the *myelocœle*; this latter, however, quickly disappears.

The cells of the somites are gradually grouped into three sets, two to the inner and lower side of the cavity, and one to its upper and outer side. The two groups on the lower and inner side are an outer, next the cavity, the **muscle plate**, and an inner, the **scleratogenous layer.** The group on the upper and outer side of the cavity is the sub-epithelial or **cutaneous lamella.**

Scleratogenous Layer. — The cells of this layer proliferate rapidly and migrate inwards, surrounding the notochord, and passing both beneath the neural tube and upwards along its lateral walls to its dorsal aspect; they intermingle above and below with the cells of the corresponding layer of the opposite side, and in front and behind with the cells of the scleratogenous layers of adjacent somites. In this way the neural tube and the notochord are gradually enveloped by a continuous sheath of mesodermal tissue, which forms the **membranous vertebral column.** This is perforated at regular intervals by the nerve-roots issuing from the spinal cord and brain, and by the vessels of supply to those structures. From its substance the vertebræ and ligaments, the greater part of the intervertebral discs, and the investing membranes of the brain and cord are afterwards developed.

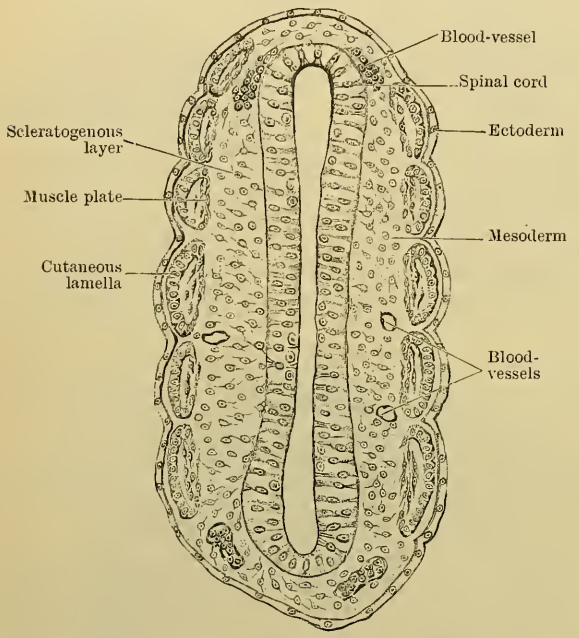


FIG. 25.—CORONAL SECTION OF A RAT EMBRYO.
Showing the relationship of the extending scleratogenous tissue to the spinal cord and to the muscle plates.

Muscle Plates. — The cells of the muscle plate layer lose their original epithelial-like characters; they elongate antero-posteriorly, become spindle-shaped and striated, and they give rise to the striped muscles of the body. For a long time the fibres developed from each muscle plate remain localised and quite distinct from the fibres developed from neighbouring segments; the masses they form are called **myotomes.** After a time, however, the fibres of neighbouring myotomes are more or less intermingled, and in the adult, except in certain situations, the intermyotomic intervals are no longer recognisable.

The main portions of the myotomes are converted into the muscle masses situated in the dorsal part of the body wall, that is, into the erectores spinæ and their main subdivisions, and the other muscles which occupy the vertebral grooves.

In the lower vertebrates the ventral ends of the myotomes descend in the somatopleure almost to the mid-ventral line, and are transformed into the muscles of the ventro-lateral walls of the body. A similar descent of the ventral ends of the myotomes into the lateral walls of the body has not been proved in the highest vertebrates. In mammals, including man, the ventral ends of the myotomes only descend for a short distance in the somatopleure, and then all trace of their characteristic structure is lost. It is presumed, however, that cells budded off from the

myotomes descend to a lower level, and that they take part in the formation of the ventro-lateral muscles.

In lower vertebrates bud-like projections pass from the myotomes in the thoracic and pelvic regions into the limb rudiments, and from these the muscles of the limbs are developed. In the highest vertebrates distinct buds from the myotomes have not been observed, but it is said that outgrowths of cells pass from the myotomes into the limb buds, where they proliferate and form the limb-muscles. The occurrence of these outgrowths into the limbs, like the descent of the lower ends of the myotomes into the ventral part of the body-wall, has not been proved in mammals; possibly it occurs, but if not, the ventral and limb-muscles of mammals must be developed from the somatopleural mesoderm.

Cutaneous Lamellæ of the Mesodermic Somites.—The cells which form

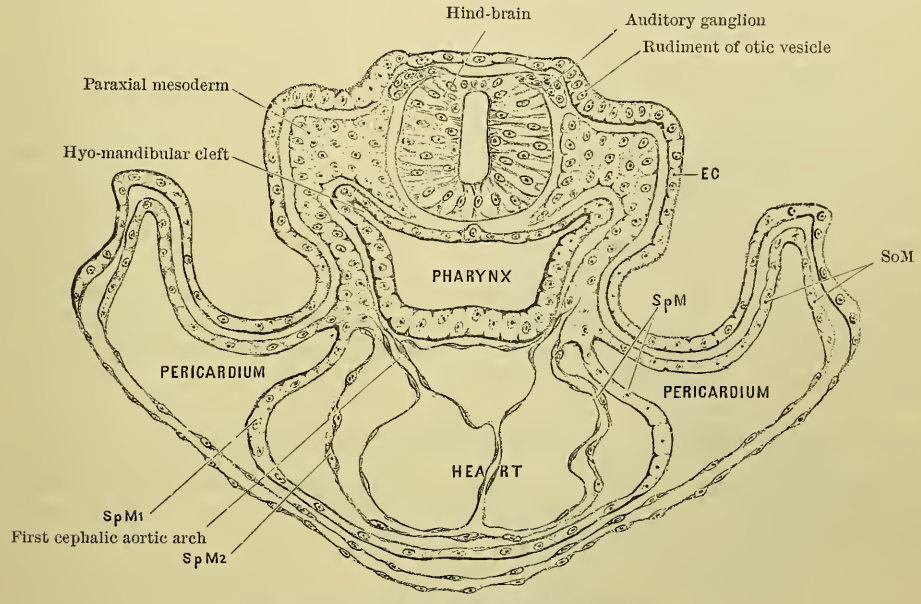


Fig. 26.—Transverse Section of a Rat Embryo.

Showing the relation of the paraxial mesoderm of the head to the lateral plates, the commencement of the formation of the otic vesicles and hyomandibular clefts, and the relation of the primitive heart to the pericardium and fore-gut.

EC. Ectoderm. SoM. Somatic mesoderm. SpM. Splanchnic mesoderm.

the outer and dorsal walls of the cavities of the mesodermal somites retain their epithelial-like characters for a longer period than those of other portions of the somites, and at the borders of the lamellæ they pass by gradual transition into the cells of the muscle plates. After a time they undergo histological differentiation, and they are utilised in the formation of the subcutaneous tissues and fasciæ on the dorsal aspect of the body, and outgrowths, which descend with the offsets of the muscle plates, enter into the formation of the ventro-lateral walls of the body.

Mesodermic Somites of the Head.—It has already been pointed out (p. 26) that protovertebral somites are not recognisable in mammals further forwards than the occipital region; but, from the evidence obtained by examination of lower vertebrates, it is believed that originally nine somites were present in the cephalic region. From the first, second, and third of these, muscle plates form which are developed into the muscles of the eyeballs. If any muscle plates are formed in connexion with the fourth, fifth, and sixth somites they disappear, leaving no traces, and the muscles developed from the remaining cephalic somites are those of the tongue and those connecting the head with the shoulder girdle.

Lateral Plates.—At an early stage, before its separation from the paraxial mesoderm, each lateral plate is divided into an outer or somatic and an inner or splanchnic layer. The somatic layer is concerned with the formation of the parietal layers of the pleural and peritoneal membranes, and with the development

of the connective tissues, fasciæ, and vessels of the ventro-lateral walls of the body; and in mammals, apparently, it also gives origin to the ventro-lateral body muscles and the muscles of the limbs. The splanchnic portions of the lateral plates form the fasciæ, the connective tissues, the smooth muscles of the walls of the alimentary canal, the heart and great blood-vessels, the visceral layers of the pleural and peritoneal membranes, the spleen, and the germinal epithelium, which becomes transformed into the mother cells of the ova and spermatozoa.

In the cephalic region, in higher vertebrates, lateral plates are not recognisable, except so far as they may be represented by the walls of the pericardium; but in some lower vertebrates lateral plates can be distinguished, corresponding in number with the cephalic somites, and it has been asserted that the muscles of the face and the muscles of mastication are developed from the lateral plates associated with the second and third cephalic somites. The subject, however, is one which is still obscure, and requires further investigation before any very positive conclusion can be arrived at.

Intermediate Cell Mass.—As already mentioned, the lateral plates and the mesodermic somites are connected by the intermediate cell masses, which are intimately associated with the development of the ducts and tubules of the genital and urinary organs in man and other mammals. On each side the mass soon separates from the mesodermic somites, and is transformed by rapid proliferation of its cells into an elongated body, the Wolffian body or primitive kidney, which projects downwards into the dorsal angle of the body cavity. In early stages it extends from the fifth somite of the body, backwards to its posterior end, but is most clearly differentiated in the middle portion. The Wolffian duct and tubules and the Müllerian duct are developed in connexion with it; after the second month of intrauterine life it degenerates, and is replaced by the permanent kidney, which is formed dorsal to its posterior extremity.

THE DEVELOPMENT OF THE PRIMITIVE ALIMENTARY CANAL.

When the cephalic, caudal, and lateral folds are established, and the general outline of the embryo is clearly defined, its dorsal and lateral surfaces and its

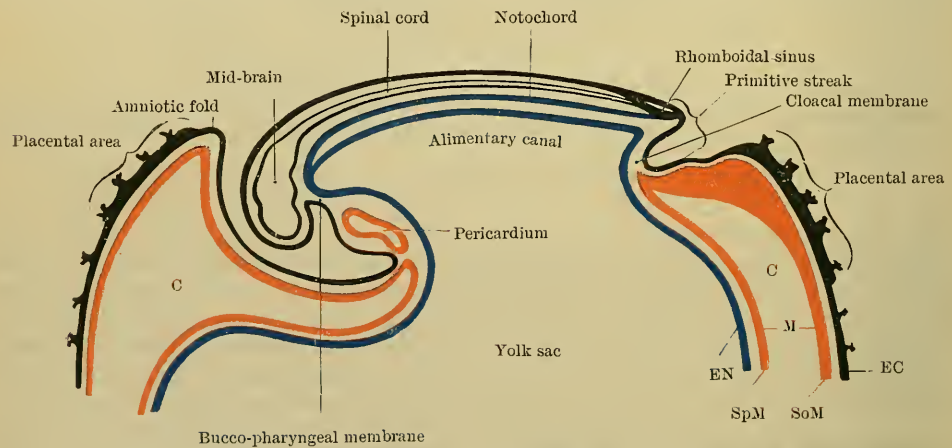


FIG. 27.—DIAGRAM OF A DEVELOPING OVUM, SEEN IN LONGITUDINAL SECTION.

The folding off of the embryo has commenced, and the downward bend of the head fold in front has invaginated the amniotic area. The tail fold is partly formed, and the primitive alimentary canal, closed in front by the bucco-pharyngeal membrane and behind by the cloacal membrane, is distinguishable; it communicates freely with the yolk sac by a wide umbilical aperture.

C. Cœlom. EN. Entoderm. SoM. Somatic mesoderm.
EC. Ectoderm. M. Mesoderm. SpM. Splanchnic mesoderm.

anterior and posterior extremities are easily recognisable, and, as the embryo is folded off from the surface of the blastodermic vesicle, a portion of the blastodermic cavity is enclosed within it; this is the primitive alimentary canal. It is simply an incomplete tubular cavity, situated beneath the notochord, which is bounded in

front by the head fold, behind by the tail fold, and laterally by the lateral folds, but is widely open below and continuous with the cavity of the yolk-sac.

As the head of the embryo grows more rapidly than any other part, the head fold is more marked than the other folds, and with its formation the pericardial area is bent round until it becomes ventral in position, its original upper and lower surfaces being reversed (Fig. 27). It is owing to this change of relative position that the ventral wall of the alimentary canal is completed in front, and it is obvious that its anterior limit corresponds to the bucco-pharyngeal area of the blastoderm. The part of the blastodermic cavity enclosed in the head fold constitutes the **fore-gut.**

The tail fold at this period is small, but it limits the primitive gut behind.

The ventral closing of the posterior end of the primitive alimentary canal to form a **hind-gut** is produced, as in the case of the fore-gut, by bending of the embryonic area. This takes place in the region of the tail fold; but the posterior part of the embryonic area retains for a considerable time its original position, and forms a connecting stalk, termed the **body-stalk**, between the embryo and the chorionic area of the blastoderm. Ultimately, however, this terminal section of the embryonic area is reversed in position, its posterior end being carried forwards till it forms the posterior boundary of the umbilical orifice, and the ventral wall of the hind-gut is thus completed.

The rest of the primitive alimentary canal constitutes the **mid-gut.** It remains for some time in free communication with the cavity of the yolk-sac, and this communication between the alimentary canal and the yolk-sac at a later stage forms a tubular passage, the **vitello-intestinal duct.**

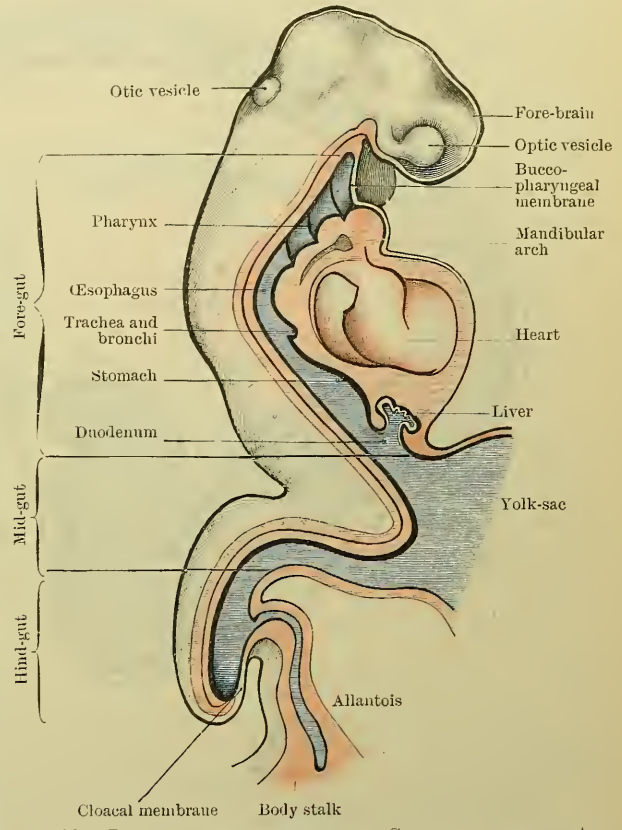


FIG. 28.—DIAGRAM REPRESENTING THE CONDITION OF THE ALIMENTARY CANAL IN A HUMAN EMBRYO ABOUT FIFTEEN DAYS OLD (modified from His).

The visceral clefts are formed, and the subdivisions of the fore-gut, together with the rudiments of the bronchi and liver, are distinct.

The entoderm forms the lining epithelium of the alimentary canal, but this is invested by the splanchnic layer of the mesoderm, which is separated from the somatopleure or body wall by the cœlom or body cavity. As the splanchnic mesoderm passes on each side to its continuity with the somatic mesoderm it forms a fold, by which the gut is suspended from the under surface of the primitive vertebral column; this fold is the **mesentery.**

When the diaphragm is formed at a later period it separates the thorax from the abdomen, and divides the cœlom into pleural and peritoneal portions.

The primitive alimentary canal is almost a straight tube, blind at both its extremities, and communicating only with the cavity of the yolk-sac. As yet there is no mouth and no anal passage or aperture. The simple tubular canal is divisible into fore-gut, mid-gut, and hind-gut, parts which are conveniently associated developmentally with definite portions of the fully-formed alimentary canal.

Thus the fore-gut is converted into the pharynx, œsophagus, stomach, and the greater part of the duodenum; whilst from the mid-gut and the hind-gut the rest of the small intestine (jejunum and ileum), and the whole length of the large intestine (cæcum, colon, and rectum), are formed. There is no sharp limit between the mid-gut and the hind-gut, or between the portions of the intestinal canal which develop from them.

Diverticular outgrowths from the entoderm of the primitive alimentary canal form the rudiments of the intestinal glands, including the liver and pancreas; of the respiratory apparatus; and of the thyroid and thymus glands. Details of the formation of these structures are given in the special description of the development of the system to which each belongs.

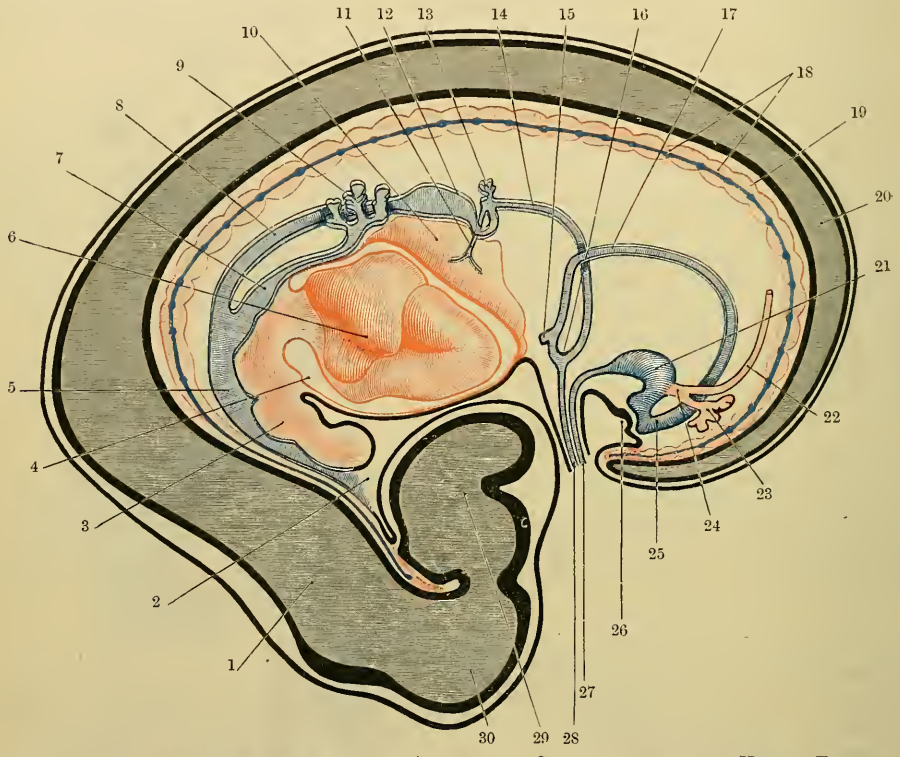


FIG. 29.—FURTHER DEVELOPMENT OF THE ALIMENTARY CANAL, AS SEEN IN A HUMAN EMBRYO ABOUT FIVE WEEKS OLD (Diagrammatic).

The tongue is well formed, the trachea and œsophagus are separated, the bronchi have commenced to branch; the duodenal curve is well formed, and the cæcum has appeared in the loop of the mid-gut. The cloaca is partially separated into genito-urinary and rectal portions.

1. Hind-brain.	7. Trachea.	13. Pancreas.	19. Vertebra.	25. Rectum.
2. Mouth.	8. Œsophagus.	14. Small intestine.	20. Spinal cord.	26. Proctodæum.
3. Tongue.	9. Lung.	15. Cæcum.	21. Bladder.	27. Allantoic diverticulum.
4. Pericardium.	10. Liver.	16. Intestinal loop.	22. Wolffian duct.	28. Vitello-intestinal duct.
5. Pharynx.	11. Bile duct.	17. Large intestine.	23. Kidney.	29. Fore-brain.
6. Heart.	12. Stomach.	18. Notochord.	24. Ureter.	30. Mid-brain.

Except with respect to the anterior part of the fore-gut, the changes in shape and position which the originally simple alimentary tube undergoes during its conversion into its final or adult form are described in the account of the development of the digestive organs; but the development of the pharynx and the structures associated with it, and the formation of the mouth and anus, may be considered now.

Development of the Pharynx and Stomatodæum.—The development of the anterior part of the fore-gut into the pharynx and the floor of the mouth is so intimately associated with the formation of a primitive mouth, the stomatodæum, that the two must to a certain extent be considered simultaneously.

The **stomatodæum** first appears as a depression between the head and the peri-

cardial region. It is produced by the downward growth of the fore-part of the head in front and the bulging forward of the pericardium behind, and it is separated from the anterior end of the fore-gut by the bilaminar bucco-pharyngeal membrane. When the stomatodæum first appears it is not enclosed laterally; but at a later period side boundaries are formed, and the space is developed into the upper part of the mouth and the nasal cavities.

The fore-gut, a relatively wide space, continuous posteriorly with the mid-gut, is at first closed anteriorly by the bucco-pharyngeal membrane, which separates it from the stomatodæum. About the fifteenth day, in the human embryo, the bucco-pharyngeal membrane disappears, the fore-gut is then thrown into continuity with the stomatodæal space, and the anterior opening of the alimentary canal is formed.

As development proceeds the cavity of the fore-gut is gradually compressed dorso-ventrally until its transverse section assumes a triangular outline; but in the earliest stages there are no indications of the various organs which are ultimately developed from its walls. After a short interval, however, two elevations appear in its ventral wall. The anterior of these is a rounded elevation, termed the **tuberculum impar**. It is situated directly behind the lower ends of two raised bars or arches, called the mandibular arches, which are growing down into the floor of the fore-gut from the anterior parts of its lateral walls. The tuberculum impar is the rudiment of the anterior two-thirds of the tongue, which is thus formed in the floor of the entodermal portion of the alimentary canal. The more posterior elevation, termed the **furcula**, is a curved ridge, which bounds a mesial longitudinal depression. It is separated from the lateral walls of the fore-gut and from the tuberculum impar by a groove, the **sinus arcuatus**. The anterior part of the furcula is transformed into the epiglottis and the margins of the upper aperture of the larynx; the median depression becomes the cavity of the larynx and of the trachea, and from its posterior end hollow outgrowths extend and form the rudiments of the epithelial lining of the bronchi and lungs. Still more posteriorly, behind the region of the furcula, a dilatation of the fore-gut is formed, which projects forwards and downwards towards the pericardium. This is the first indication of the stomach.

Visceral Clefts and Visceral Arches.—In the lateral wall of the anterior part of the fore-gut, on each side, four incomplete and more or less transverse clefts, the visceral clefts, appear. They are due to outward linear pouchings of the entoderm, and corresponding, but less marked, inward depressions of the ectoderm. The anterior cleft is the best marked, and the rest diminish in size from before backwards. At the bottoms of the clefts the ectoderm and the entoderm are in contact, but the thin membranes thus formed, which intervene between the cavity of the fore-gut and the exterior, are only exceptionally and abnormally perforated in the human subject, though in lower vertebrates they invariably disappear, and the pharyngeal or anterior part of the fore-gut is thrown into continuity, laterally, with the exterior by a number of narrow slits, the gill slits, which are used for respiratory purposes. In man and other mammals, however, the floors of the second, third, and fourth clefts are utilised in the formation of the sides of the neck; that of the first cleft is transformed into the tympanic membrane, which separates the external auditory meatus from the cavity of the tympanum.

In the further consideration of the fate of the visceral clefts, it must be borne in mind that each consists of an inner or entodermal portion and an outer or ectodermal portion. The inner part of the first cleft is converted into the tympanum and the Eustachian tube, and the outer part becomes the external auditory meatus. No traces of the outer part of the second cleft are left, but a portion of the inner part can be recognised as a slight depression above the tonsil in the lateral wall of the pharynx and in a recess, the fossa of Rosenmüller, behind the pharyngeal end of the Eustachian tube. Both the outer and inner portions of the third and fourth clefts disappear, but from their inner parts diverticula are given off which form the rudiments of the thymus and the lateral lobes of the thyroid body. The diverticula from which the thymus is developed are derived from the third clefts, whilst each lateral lobe of the thyroid body, in the majority of mammals, is formed by a diverticulum from the fourth cleft, but in some mammals the lateral lobes are

derived from the median diverticulum, and the outgrowths from the posterior parts of the fourth clefts constitute the post-branchial bodies.

The margins of the visceral clefts are thickened by the growth of the mesoderm between the entodermal and ectodermal layers, and they are moulded into a series of five rounded bars, the **visceral arches**, of which the fifth is not recognisable externally, though it is easily seen internally. The dorsal extremities of the arches terminate at the sides of the head below the level of the neural tube, and in the early stages the ventral ends rest upon the pericardial region. When the neck is formed, it grows forwards from the pericardial region and carries with it the lower ends of the visceral arches, which henceforth terminate in its ventral wall. As the visceral arches are carried forwards the head is strongly curved towards the ventral aspect, and the lower ends of the visceral arches are pushed backwards over each other till the fourth is overlapped by the third, and the third by the second.

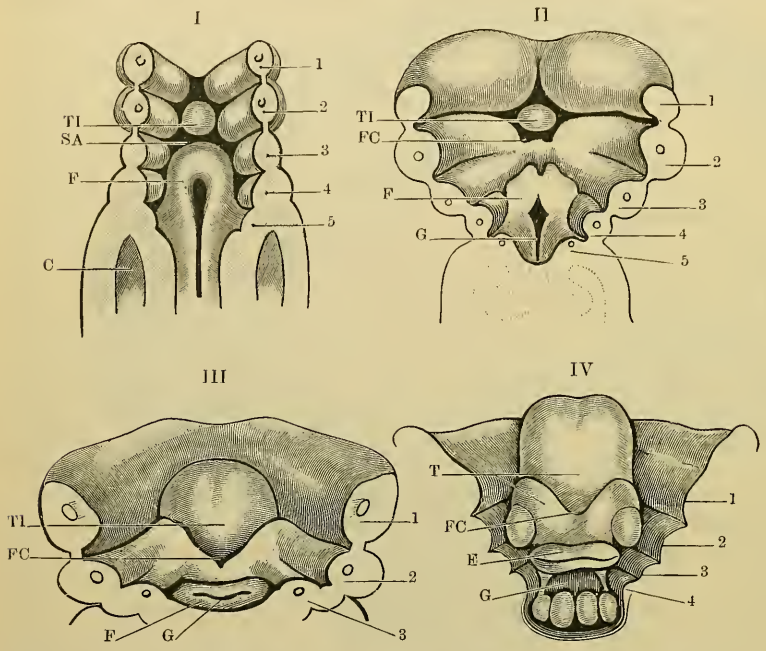


FIG. 30.—STAGES IN THE FORMATION OF THE TONGUE AND UPPER APERTURE OF THE LARYNX IN THE HUMAN EMBRYO (after His).

I. Embryo 14 days old. II. Embryo 23 days old. III. Embryo 28 to 30 days old. IV. Embryo 2 months old.

1, 2, 3, 4, 5 } Visceral arches.

C. Cœlom.
E. Epiglottis.
F. Furcula.
FC. Foramen cæcum.
G. Glottis.
SA. Sinus arcuatus.
T. Tongue.
TI. Tuberculum impar.

The first arch is the mandibular, the second the hyoid, the third the thyro-hyoid; the fourth and fifth have no special designations. Each arch is covered—externally by ectoderm, internally by entoderm, and its core is formed of mesoderm, in which there is developed a bar of cartilage and a blood-vessel called a cephalic aortic arch.

At first each arch is limited to the side wall of the fore-gut; but after a time it is prolonged into the ventral wall, encroaching, with the exception of the first, upon the sinus arcuatus.

The **first, or mandibular arch,** is formed between the first visceral cleft and the bucco-pharyngeal membrane. As it develops it forms the lateral and lower boundaries of the stomatodæal space, and it grows downwards till it meets its fellow of the opposite side in the ventral middle line, immediately in front of the tuberculum impar. The greater part of this arch is converted into the lower jaw and the soft tissues which invest it. From its upper part a process grows forwards, the **maxillary process,** from which the upper lateral part of the face, between the orbit and the mouth, is developed, and in which the superior maxillary, the malar, and the palate bones, and possibly the internal pterygoid plate also, are developed and ossified.

From the posterior border of the outer aspect of the mandibular arch the tragus and a portion of the helix of the pinna of the external ear are formed. The cartilaginous bar in its interior is known as **Meckel's cartilage.** It forms the primitive

skeleton of the arch. Its upper and lower extremities are ossified and remain in the adult, the former as the malleus, and possibly the incus, and the latter as the symphysial part of the lower jaw. The remainder of the cartilaginous bar disappears, but the fibrous membrane which surrounds the lower section of the intermediate part is ossified and converted into the main part of the lower jaw, whilst that round the upper section of the intermediate portion persists as the spheno-mandibular ligament. The blood-vessel developed in the mandibular arch is, for the main part, a transitory structure, but its ventral section is converted into the internal maxillary, superficial temporal, facial and lingual arteries.

The **second** and **third arches** are continued downwards into the floor of the pharyngeal portion of the fore-gut. There, converging, they insinuate themselves between the tuberculum impar and the furcula, across the anterior part of the sinus arcuatus, and uniting together form a transverse bar. This rapidly changes into a semilunar ridge which first embraces, and afterwards fuses with the posterior part of the tuberculum impar, and it forms the posterior third of the tongue.

The **second arch** takes part in the formation of the side and anterior part of the neck. From its anterior border externally a part of the helix, the antihelix, the antitragus, and the lobule of the pinna of the external ear are developed. The lower and upper portions of its cartilaginous bar—the hyoid bar—are ossified; the lower portion forms part of the body and the small cornu of the hyoid bone on its own side, and the upper portion is converted into the intra- and extra-temporal sections of the styloid process (the tympano-hyal and stylo-hyal portions of the styloid process of the temporal bone). The fibrous tissue of the intermediate part of the hyoidean bar persists in the adult as the stylo-hyoid ligament. The blood-vessel of the hyoid arch, the second cephalic aortic arch, almost entirely disappears, but from its ventral extremity the ascending pharyngeal, occipital, and posterior auricular arteries are probably developed.

The **third visceral arch** forms part of the neck posterior to the region of the second arch, and, as already pointed out, its lower end takes part in the formation of the posterior part of the tongue. The upper and middle parts of its cartilaginous bar disappear, but the lower part persists, and is converted into the posterior part of the body and the great cornu of the hyoid bone on its own side. Its blood-vessel, the third cephalic aortic arch, becomes the lower part of the stem of the internal carotid artery.

The **fourth** and **fifth visceral arches** also enter into the formation of the neck, but their exact limits in the adult cannot be defined. Of the upper sections of their cartilaginous bars no trace remains in the adult, but their lower portions are believed to enter into the formation of the thyroid cartilage of the larynx. The blood-vessel of the fourth arch on the right side becomes part of the right subclavian artery, that on the left side is converted into the arch of the aorta. The vessels of the fifth arches form portions of the pulmonary arteries, and that on the left side forms also the ductus arteriosus.

Further Development of the Ventral Wall of the Fore-gut in the Region of the Furcula.—The sinus arcuatus which surrounds the furcula disappears to a great extent as development proceeds, but certain parts of it remain and are recognisable in the adult. The anterior portion immediately in front of the furcula is divided into two parts as the lower ends of the second and third arches of the two sides converge and fuse in the ventral wall of the pharyngeal portion of the fore-gut; the middle portion of the sinus, in front of the transverse bar formed by this fusion, persists in the adult as the foramen cæcum of the tongue, and at a very early period a diverticulum grows backwards from it in the floor of the pharynx, dorsal to the cartilage bars which form the hyoid bone, but ventral to the rudiments of the thyroid cartilage. This diverticulum is the **thyro-glossal duct.** As soon as it reaches the level of the fourth visceral clefts it enlarges, unites with the diverticula from those clefts which form the lateral lobes of the thyroid body, and is itself converted into the isthmus of the thyroid, its pyramidal process and the thyro-glossal duct or the fibrous cord into which that duct becomes converted in the adult. Occasionally the thyro-glossal duct is not wholly transformed into a fibrous cord, but portions of it remain in the form of isolated vesicles, lined with

columnar or cubical epithelium, or as cords of cells, and these occasionally undergo abnormal development, forming tumours at the base of the tongue or in the upper part of the neck.

The portion of the sinus arcuatus which lies behind the conjoined lower extremities of the second and third arches of opposite sides, and in front of the furcula, persists in a modified form in the adult, and is recognisable as glosso-epiglottidean pouches or valleculæ at the base of the tongue.

The furcula and the groove in the ventral wall of the fore-gut, which it embraces antero-laterally, are both of considerable importance. The anterior part of the furcula is situated in the ventral wall of the pharyngeal portion of the fore-gut, but its backward prolongations and the furrow between them lie in what may be termed the intermediate part of the fore-gut, that is, in that part of the fore-gut which intervenes between the pharyngeal and stomach regions. Gradually the furrow deepens, and its posterior extremity dilates on each side. Afterwards the margins of the furrow coalesce from behind forwards, and in this manner the cavity of the furrow is separated from the fore-gut, its walls are converted into the trachea and the lower part of the larynx, whilst the diverticula which are projected from its posterior end form the rudiments of the bronchi. The fusion of the margin of the furrow ceases a short distance behind its anterior extremity, which latter persists as the superior aperture of the larynx. The anterior part of the furcula, which bounds this aperture in front, becomes the epiglottis, and its lateral extensions, which form the margins of the aperture, are converted into the arytenoepiglottidean folds in the substance of which the arytenoid cartilages and the cartilages of Santorini and Wrisberg (cuneiform cartilages) are formed.

DEVELOPMENT OF THE MOUTH AND THE NOSE.

The nose is formed entirely from the stomatodæum. The mouth has a double origin; the roof and fore-part, including the teeth, are developed from the stomatodæum, whilst the floor and the tongue are developed from the pharyngeal portion of the fore-gut.

It has already been pointed out (p. 34) that the stomatodæal depression lies between the anterior part of the head (*i.e.* the tissues forming the base of the primary fore-brain) and the pericardial region, and that it is separated posteriorly from the fore-gut by the bucco-pharyngeal membrane. At first it has no distinct lateral boundaries, but subsequently the mandibular arches, which are developed at the sides of the bucco-pharyngeal membrane, project forward beyond the membrane and form lateral limits of the depression. If the stomatodæal space is examined from the front at this period the following boundaries are recognisable:—Above and in front is the projecting anterior part of the head which is termed the **fronto-nasal process,** laterally are the mandibular arches, and below and posteriorly is the anterior part of the pericardial region. After a short time the lower ends of the mandibular arches meet in front of the pericardial region, and, fusing together, form the posterior or lower margin of the aperture; simultaneously the lateral boundaries of the space are still further completed by the forward growth of a nodular projection, the **maxillary process,** from the upper end of each mandibular arch. About the fifteenth day the bucco-pharyngeal membrane disappears, and the stomatodæal space and pharynx are thenceforth continuous. No trace of the bucco-pharyngeal membrane is recognisable in the adult, but its position may be represented by an imaginary plane extending from the anterior part of the basi-sphenoid above to the base of the alveolar process of the lower jaw, on its lingual surface, below.

Whilst the boundaries of the stomatodæal space are being defined, two oval depressions, lined with thickened epithelium, appear in its upper boundary on the lower and anterior surfaces of the fronto-nasal process; these are the **olfactory pits** or depressions. A portion of the epithelium of their walls is separated off and takes part in the formation of the olfactory bulbs, whilst the remainder is transformed into the olfactory epithelium, from which the olfactory nerve-fibres grow inwards to the olfactory bulbs. As the olfactory pits deepen they grow backwards into the roof of the stomatodæal space, and at the same time they separate the lower portion

of the fronto-nasal process into three parts, constituting a median and two lateral nasal processes. At each lateral angle of the median nasal process a spheroidal elevation, the **globular process**, appears. The part of the median nasal process which intervenes between the two globular processes is divided into two areas, an upper triangular and a lower quadrilateral, by the appearance of a transverse ridge, which is afterwards moulded into the tip of the nose. The upper triangular area becomes the dorsum of the nose, and the lower quadrilateral area forms the columella, *i.e.* the lower and anterior part of the septum between the anterior

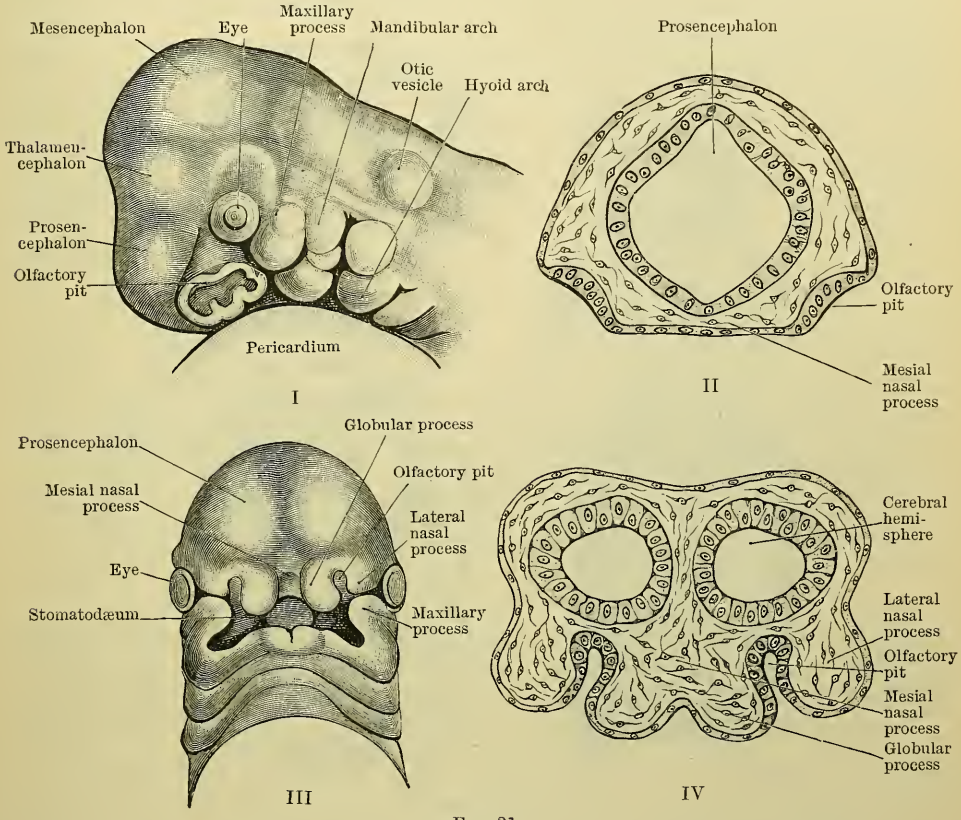


FIG. 31.

I. Side view of the head of human embryo about 27 days old, showing the olfactory pit and the visceral arches and clefts (from His).

II. Transverse section through the head of an embryo, showing the relation of the olfactory pits to the fore-brain and to the roof of the stomatodæal space.

III. Head of human embryo about 29 days old, showing the division of the lower part of the mesial frontal process into the two globular processes, the intervention of the olfactory pits between the mesial and lateral nasal processes, and the approximation of the maxillary and lateral nasal processes, which, however, are separated by the oculo-nasal sulcus (from His).

IV. Transverse section of head of embryo, showing the deepening of the olfactory pits and their relation to the hemisphere vesicles of the fore-brain.

nasal apertures. The globular processes are utilised in the formation of the **philtrum** or middle part of the upper lip, and the lateral nasal processes form the alæ of the nose or lateral boundaries of the anterior nasal apertures. As the olfactory pits deepen and grow backwards into the roof of the stomatodæum the maxillary processes grow forwards from the lateral boundaries of that space, that is from the upper ends of the mandibular arches, and pass beneath the eyes, which now form distinct prominences on the sides of the head. The upper borders of the maxillary processes come into contact with the lateral nasal processes from which they are temporarily separated by grooves, the **oculo-nasal sulci**. These latter pass from the depressions round the eyeballs, the rudimentary conjunctival sacs, to the margins of the nasal pits. The anterior extremities of the maxillary processes impinge

upon the globular processes, and ultimately their upper borders and anterior extremities fuse with the lateral nasal and globular processes, completing the lower boundaries of the anterior nasal orifices and the lateral parts of the primitive upper lip. At the same time the oculo-nasal sulci are converted first into solid cords of cells, and afterwards into the lachrymal sacs and the nasal ducts, which henceforth constitute the channels of communication between the conjunctival sacs and the nose.

The result of the ingrowth of the maxillary processes and their fusion with the

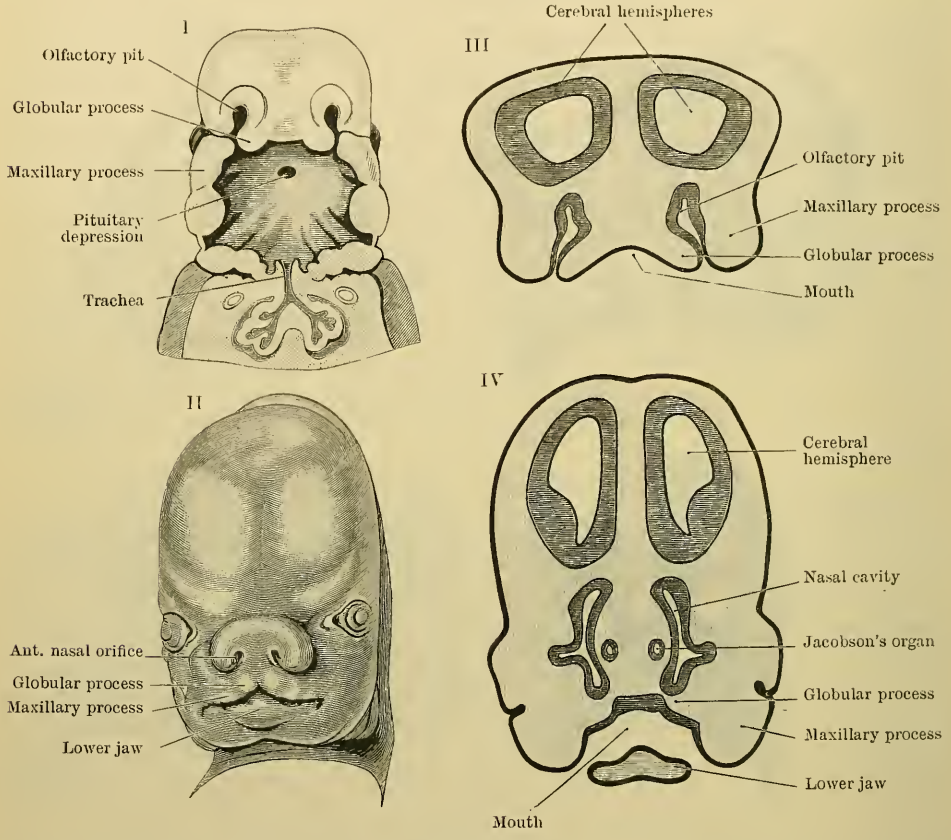


FIG. 32.

I. Portion of the head and neck of a human embryo 32 days old. The floor of the mouth and pharynx and the ventral part of the anterior portion of the body have been removed. By the approximation of the globular and maxillary processes the boundaries of the anterior nares are almost complete, but the olfactory pits still open in the whole of their lengths into the roof of the mouth (from His).

II. Transverse section of the head of an embryo, showing the close apposition of the globular and maxillary processes.

III. Head of human embryo about 2 months old, showing the union of the globular processes and their fusion with the maxillary processes. The anterior nasal apertures are now completely defined (from His).

IV. Transverse section of the head of an embryo, showing the fusion of the maxillary processes with the globular processes, and the separation anteriorly of the nose from the mouth.

lateral nasal and globular processes is the division of the large orifice which led into the stomatodæal space into three parts—a large lower, and two smaller upper apertures. The lower opening is the aperture of the mouth; it is bounded below by the united mandibular arches, and above by the fused mesial nasal and maxillary processes. The smaller upper openings are the anterior nares, which on their first formation are merely foramina of communication between the exterior and the upper part of the stomatodæal space; the latter is not yet separated into nasal and oral chambers.

Formation of the Palate and the Separation of the Nasal and Buccal Cavities.—This separation is effected by the formation of the palate, which is developed to a slight extent by the backward growth of the globular processes

along the roof of the space as a pair of ridges, termed the **nasal laminæ**, which fuse together to form a small anterior portion of the palate, viz. the intermaxillary process, in which the intermaxillary parts of the superior maxillæ are formed. The remaining and greater part of the palate is formed by two ledge-like ingrowths, one from the inner surface of each maxillary process, which meet and fuse anteriorly with the intermaxillary process, and behind this with each other. In these projections the palatal processes of the superior maxillæ and the horizontal plates of the palate bones are formed, and by their fusion the upper part of the stomatodæal space is separated off from the remainder as a common nasal chamber which communicates in front with the exterior by the anterior narial orifices, and behind with the pharyngeal portion of the fore-gut by the choanal apertures or posterior nares. The lower part of the stomatodæal space and the front part of the fore-gut together form the mouth or buccal cavity; this opens anteriorly by a transverse aperture, the boundaries of which have already been described, and posteriorly it is in direct continuity with the pharynx.

The division of the common nasal chamber into two parts commences before its separation from the mouth is completed, and it is brought about by the development

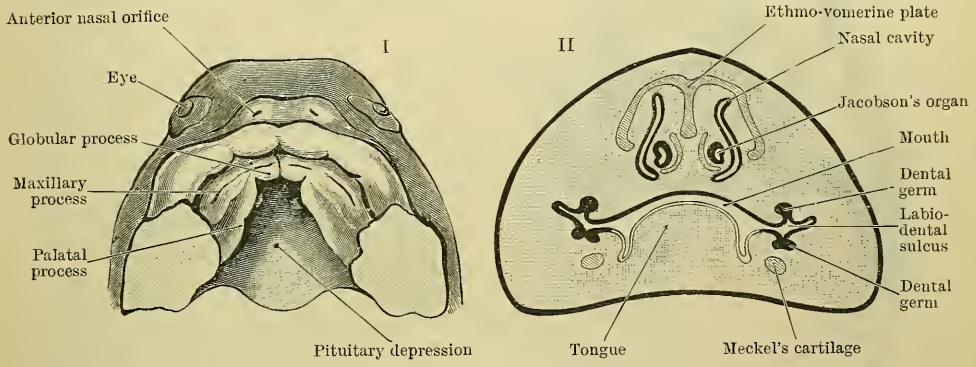


FIG. 33.

I. Portion of the head of a human embryo about $2\frac{1}{2}$ months old (His). The lips are separated from the gums, and the line of the common dental germ is visible in the latter. The palatal processes are growing inwards from the maxillary processes.

II. Transverse section of the head of an embryo after the fusion of the palatal processes of the maxillary processes with the nasal septum, which grows backwards from the fused globular processes.

of a septum which is continuous anteriorly with the fused nasal laminæ, and which grows downwards and backwards from the mesial part of the under aspect of the fronto-nasal process. This septum fuses below with the conjoined margins of the palatal ledges of the maxillary processes, and a vertical plate of cartilage soon develops in its interior, which is continuous above with the cartilaginous base of the cranium (basi-cranial axis). A portion of this septal cartilage remains in the adult as the septal cartilage of the nose, and the remainder is more or less completely replaced by the vertical plate of the ethmoid bone and by the vomer. The lateral wall of each nasal chamber is formed, in the lower part of its extent, by the maxillary process of the mandibular arch, in which the superior maxillary, malar, and palate bones, and possibly the internal pterygoid plate, are developed, and in the upper part by the outer boundary of the original nasal pit, which now forms only the upper part of the nasal cavity. In this upper section of the outer wall an outgrowth of the basi-cranial axis projects downwards, and is developed into the lateral mass of the ethmoid bone; probably it also takes part in the formation of the inferior turbinal bone.

The fusion of the three segments of the palate commences anteriorly at the eighth week by the union of the maxillary and globular processes; it passes backwards and is completed by the fusion of the posterior parts of the palatal ledges of the maxillary processes about the tenth week. To the non-completion of this fusion the various cases of hare-lip and cleft palate are due.

Organ of Jacobson.—The organs of Jacobson are rudimentary structures in man.

They lie in the lower and anterior part of the nasal septum, one upon each side. They are developed as small diverticula which grow backwards and upwards in the substance of the septum, and their points of commencement are situated immediately above the intermaxillary segment of the palate. Each diverticulum is partially surrounded, on its inner side, by a cartilaginous capsule, it ends blindly behind, and it opens anteriorly close to the floor of the nose in the region of Stenson's foramen—a small aperture left between the premaxillary and maxillary sections of the bony palate.

Pituitary Body.—The pituitary body is formed partly from the floor of the first primary cerebral vesicle, and partly from the roof of the stomatodæal space. The stomatodæal portion appears as a small pouch, Rathke's pouch, which grows upwards into the base of the head immediately in front of the dorsal margin of the bucco-pharyngeal membrane and the anterior end of the notochord, and behind the fore-brain. It is lined by ectoderm, and soon becomes a conical vesicle which lies beneath the base of the fore-brain. Its orifice of communication with the stomatodæal space is gradually constricted until the lumen disappears, and then for a time the vesicle is connected with the surface by a solid cord of ectodermal cells. This also disappears, and the vesicle is embedded in the base of the head in a region above and between those parts of the basal axis which afterwards are transformed into the basi- and pre-sphenoid elements of the sphenoid bone.

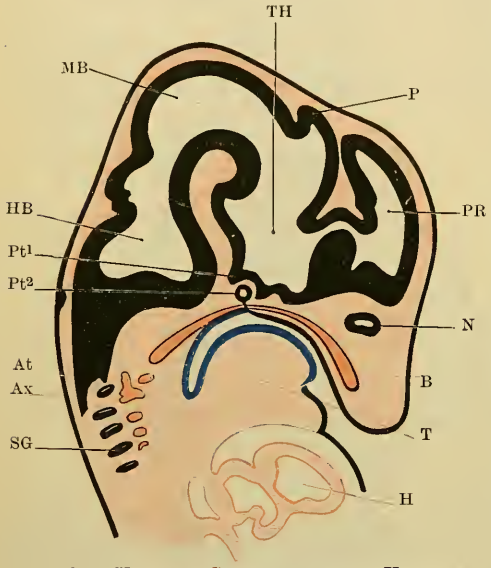


FIG. 34.—VERTICAL SECTION THROUGH HEAD OF RAT EMBRYO.

Showing the formation of the two parts of the pituitary body (diagrammatic).

(Ectoderm is represented in black, entoderm in blue, and mesoderm in red.)

At. Atlas.
Ax. Axis.
B. Cartilaginous basi-cranial axis.
H. Heart.
HB. Hind-brain.
MB. Mid-brain.
N. Part of nasal cavity.
P. Pineal body.
PR. Cerebral hemisphere.
Pt^1. Cerebral part of pituitary body.
Pt^2. Buccal part of pituitary body.
SG. Spinal ganglion.
T. Tongue.
Th. Thalamencephalon.

During the period of its formation and separation the ingrowth from the stomatodæum comes into relation posteriorly with a small diverticulum from the floor of the fore-brain, which dilates at its lower end to form the posterior or cerebral lobe of the pituitary body, whilst its upper part remains as the infundibulum, the connecting stalk between the pituitary body and the floor of the third ventricle of the brain. The anterior or stomatodæal lobe of the pituitary body is much larger than the posterior lobe, which it surrounds and conceals both in front and at the sides.

It is evident that in the early stages the pituitary body consists of two ectodermal vesicles, the cavity of the posterior vesicle is continuous with the cerebral tube, and that of the anterior vesicle with the cavity of the primitive mouth. The cavity of the posterior vesicle is generally obliterated, and though nervous structures are for a time developed in its walls they entirely disappear in man and are replaced by vascular connective tissue. Occasionally a small part of the cavity remains as a minute vesicle lined with columnar ciliated epithelium.

The cavity of the anterior vesicle persists, it sends out numerous diverticula, and is gradually converted into a number of tubular spaces, lined with cubical or columnar cells, united together by vascular connective tissue which has grown amidst the tubules from the surrounding mesoderm.

THE EXTERNAL EAR, THE TYMPANIC CAVITY, AND THE EUSTACHIAN TUBE.

The external ear, the tympanic cavity, and the Eustachian tube are all developed from the first visceral cleft and its boundaries. The cleft lies between the mandibular (first) and the hyoid (second) visceral arch in the side wall of the pharyngeal portion of the fore-gut, and, before a neck is developed, it extends from just ventral to the otic vesicle, which lies at the side of the hind-brain, above, to the pericardial region below. The membrane which lies at the bottom of the cleft consists in the early stages of ectoderm and entoderm, but in a short time a thin layer of mesoderm grows between the two primary layers, and the trilaminar septum is ultimately converted into the tympanic membrane which separates the external from the middle ear.

The differentiation of the outer part of the cleft is initiated by the appearance of six tubercles round its margins, which are afterwards transformed into the several parts of the pinna.

Two tubercles are formed anteriorly on the mandibular arch, one at the dorsal end of the cleft and three posteriorly on the hyoid arch. The two tubercles on the mandibular arch are a small lower, the **tuberculum tragicum,** and a larger upper, the **tuberculum anterius helicis.** The tubercle at the upper end of the cleft is the **tuberculum intermedium helicis.** The upper tubercle on the hyoid arch is the **tuberculum anthelicis,** the middle is the **tuberculum antitragicum,** and the lowest is the **tuberculum lobulare.** Shortly after the appearance of the tubercles a process, the **caudal process,** grows backwards and downwards, from the posterior part of the tuberculum intermedium helicis, behind the tuberculum anthelicis and the tuberculum antitragicum to the tuberculum lobulare, with which it fuses. The tuberculum tragicum remains more or less distinct, and it forms the prominence called the tragus which lies in front of the concha and external auditory meatus.

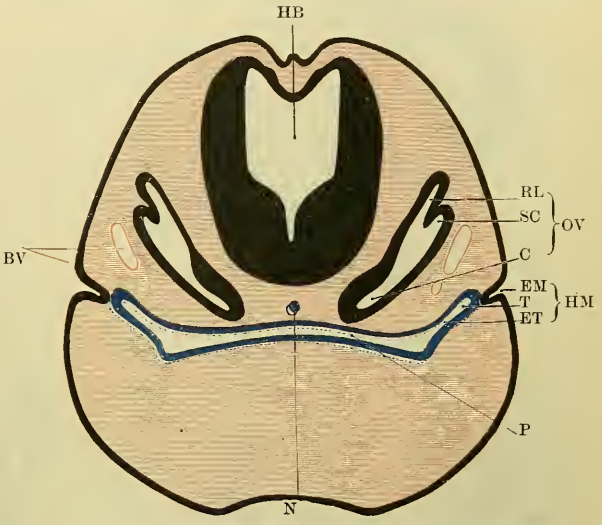


FIG. 35.—TRANSVERSE SECTION THROUGH THE HEAD OF A RAT EMBRYO.

Showing the rudiments of the three parts of the ear and their relation to the hyo-mandibular cleft.

BV.	Blood-vessels.	N.	Notochord.
C.	Cochlea.	OV.	Otic vesicle.
EM.	Ext. auditory meatus.	P.	Pharynx.
ET.	Eustachian tube.	RL.	Recessus labyrinthii.
HB.	Hind-brain.	SC.	Semicircular canal.
HM.	Hyo-mandibular cleft.	T.	Tympanum.

The two tubercles of the helix and the caudal process unite to form the helix or marginal portion of the pinna; this terminates below in the lobule which is developed from the tuberculum lobulare. The tuberculum anthelicis and the tuberculum antitragicum are the rudiments respectively of the antihelix and the antitragus, and the latter unites below the lower part of the cleft with the rudiment of the tragus, forming the lower boundary of the outer part of the external meatus. It should be noted that in the early stages the tuberculum anterius helicis lies in front of the outer part of the first visceral cleft, but it does not retain this position in the later stages during which the cleft is relatively reduced in size, and when development is completed and the outer part of the cleft is transformed into the external auditory meatus the commencement of the helix, which is developed from the tuberculum anterius helicis, is situated just above the outer extremity of the external meatus.

The outer part of the cleft is moulded into the external auditory passage. It remains relatively shallow and devoid of bony boundaries till after birth, but in the subcutaneous tissue round the lower margin of the tympanic membrane an incomplete ring of bone is formed during the third month, and at an earlier period, above the upper part of that membrane, the rudiment of the squamous part of the temporal bone appears. To the outer side of the tympanic ring in the subcutaneous tissue of the pinna and the outer part of the external auditory passage three pieces of cartilage appear, and they afterwards join to form the cartilage of the pinna and the external auditory meatus.

After birth the external meatus is deepened by the outgrowth of the tympanic ring below and of the squamous part of the temporal bone above, together with a coincident increase of the outer part of the canal.

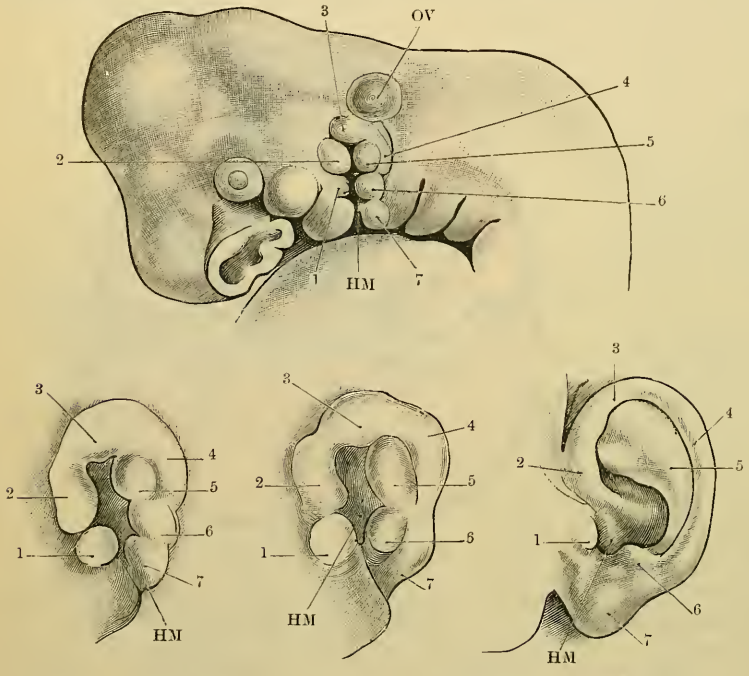


Fig. 36.—Figures, modified from His, illustrating the Formation of the Pinna.

1. Tuberculum tragicum = Tragus.
2. ,, anterius helicis
3. ,, intermedium helicis } Helix.
4. Cauda helicis
5. Tuberculum anthelicis = Antihelix.
6. Tuberculum antitragicum = Antitragus.
7. Tuberculum lobulare = Lobule.
HM. Hyo-mandibular cleft.
OV. Otic vesicle.

The **tympanic cavity** and the **Eustachian tube** are both formed from the inner part of the first visceral cleft, and consequently they are both lined by entoderm.

The tympanic cavity is developed from the dorsal or upper end of this portion of the cleft, and it is prolonged upwards on the outer side of the otic vesicle which simultaneously descends in the tissues of the head. Thus the upper end of the inner portion of the cleft, which is somewhat dilated, comes to lie between the otic vesicle, which is developed into the internal ear on the inner side, and the tympanic membrane which separates it from the external auditory meatus on the outer side, and it remains in the adult as a laterally compressed space, the tympanic cavity, which is continuous through the Eustachian tube with the upper part of the pharynx. In the mesoderm round the inner, upper, and back part of the cavity the petrous part of the temporal bone is developed and ossified, and in the lower and anterior part the tympanic ossification extends outwards during the formation of the tympanic plate.

The upper part of the tympanic space is prolonged backwards between the ossifying petrous and squamous parts of the temporal bone, where it forms a recess known in the adult as the mastoid antrum, from which at a later period diverticula are projected into the mastoid portion of the temporal bone, forming the mastoid air cells.

The lower portion of the inner part of the cleft is moved obliquely forwards. As development proceeds it is contracted and carried downwards and forwards in front of the developing otic vesicle. It is the rudiment of the Eustachian tube, and, as the septum which separates the nasal chambers from the mouth is formed,

its lower end attains a position just behind and at the side of the posterior narial orifice in the upper and lateral part of the pharynx. Apparently, therefore, the lower end of the Eustachian tube has a much higher position than that originally occupied by the lower end of the cleft from which it is formed, for it will be remembered that the lower end of the first visceral cleft is situated, in the early stages, at the side of the tuberculum impar from which the anterior two-thirds of the tongue is formed. This alteration in relative position is due, however, not to elevation of the lower end of the first visceral cleft during its transformation into the Eustachian passage, but to the enormous downgrowth of the mandibular arches, which carry with them the tongue, as they enlarge to form the lower jaw.

THE HIND-GUT, THE ANAL PASSAGE, AND THE POST-ANAL OR TAIL-GUT.

By the formation of the mouth the primitive alimentary canal opens anteriorly; it remains closed posteriorly until a later date, when the anal passage and orifice are developed.

The posterior end of the hind-gut which is enclosed in the tail-fold is termed the cloaca. The **cloaca** is dilated, and, assuming a conical form, receives the terminations of the genito-urinary ducts. It is bounded postero-inferiorly by the **cloacal membrane** which extends from the root of the tail to the body stalk by which the embryo is attached to the chorion. The cloacal membrane is modified from the posterior part of the primitive streak; this remains on the surface of the body after the anterior part has been separated and enclosed during the completion of the posterior part of the neural canal, and it forms a septum between the cavity of the cloaca and the exterior. It consists at first of ectoderm and entoderm alone, and it is only at its lower and anterior part that it is subsequently invaded to a slight extent by mesoderm.

During the second month of intrauterine life the cloaca is divided into a ventral or genito-urinary, and a dorsal or rectal section, by the formation and fusion of lateral folds, which gradually unite, from before backwards, till finally the posterior end of the septum approaches and fuses with the cloacal membrane, and the rectum is separated from the genito-urinary chamber. Before this separation is completed an eminence appears in the region of the anterior part of the cloacal membrane at the junction of the ventral surface with the posterior extremity of the body, *i.e.* in that part which afterwards becomes the region of the symphysis pubis. This eminence is the **genital eminence**, and from it are formed the penis in the male and the clitoris in the female. The genital eminence is surrounded by an oval fold of skin, **genital fold**, which extends from the front of the eminence to the root of the tail and encloses a shallow fossa, the **cloacal fossa**, at the bottom of which is the **cloacal membrane**. The posterior part of the cloacal fossa is afterwards separated from the anterior part by a transverse fold, the **perineal fold**, which crosses the external surface of the cloacal membrane in a position which corresponds internally with that occupied by the lower end of the septum separating the genito-urinary from the rectal portions of the cloacal. The posterior part of the cloacal fossa, behind the transverse fold, is the proctodæal depression or **proctodæum**; at first its long axis lies transversely, afterwards it assumes a triangular and then a circular form, the sphincter ani muscle develops in its walls, and it is transformed into the greater part, if not the whole, of the anal canal of the adult. It is separated from the rectum by the posterior part of the cloacal membrane, but when that disappears, at a date which has not yet been definitely ascertained, but probably about the third month, the anal passage forms the canal by which the rectum communicates with the exterior of the body.

The orifices of the alimentary canal are thus completed.

The Post-anal or Tail-Gut.—When the hind-gut is first enclosed there is no tail, but a rudimentary tail is subsequently developed as an outgrowth from the dorsal end of the tail-fold, *i.e.* from the posterior extremity of the body of the embryo. As the tail is formed, a narrow tube, which communicates in front with the hind-gut, is developed within it. This is called the post-anal or tail-gut. As a rule it only exists for a short

time, disappearing from before backwards about the period when cartilage begins to be formed in the body and limbs, and before the cloaca is divided into its rectal and genito-urinary portions. In the few cases in which it persists it retains its continuity with the rectum, which is formed from the dorsal part of the cloaca.

The tail-gut appears in the human subject when the embryo is 3 mm. long, and the rudimentary tail is just visible as a small nodule. When the embryo attains the length of 4·8 mm. the anterior part of the tail-gut begins to degenerate, its cavity disappears, and it is converted into a solid cord of cells which is still attached in front to the hind-gut. In embryos 11·5 mm. long, when the tail has been enclosed in the posterior part of the body, the connexion of the tail-gut with the hind-gut is lost, and the tail-gut is represented by a small vesicle with a short cord of degenerating cells attached to its anterior part.

In larger embryos the tail-gut entirely disappears. When, as in the human subject, the rudimentary tail is eventually embedded in the posterior end of the body, any rudiments of the tail-gut which persist will be found in this situation; it is stated that such rudiments occasionally develop into tumour formations. In mammals with free tails, rudiments of the tail-gut may be met with in any part of the tail, and apparently the anterior portion occasionally persists and maintains its connexion with the rectum, from which it extends backwards as a narrow and blind diverticulum.

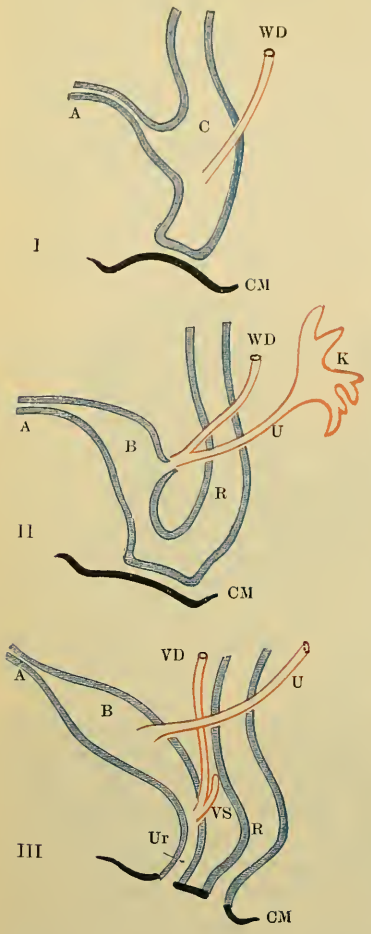


FIG. 37.—DIAGRAMS showing the separation of the cloacal part of the hind-gut into genito-urinary tract and rectum.

A.	Allantoic stalk.	U.	Ureter.
B.	Bladder.	Ur.	Urethra.
C.	Cloaca.	VD.	Vas deferens.
CM.	Cloacal membrane.	VS.	Vesicula seminalis.
K.	Kidney.	WD.	Wolffian duct.
R.	Rectum.		

THE LIMBS.

Though the body of the embryo begins to assume definite form as soon as it is folded and nipped off from the rest of the ovum, it does not present any distinguishable human characteristics until the anterior and posterior limbs are formed. There are no traces of these before the third week of intrauterine life when two longitudinal ridges, the **Wolffian ridges**, are developed, one on each lateral surface of the body, just external to the outer margins of the mesodermic somites, and opposite the line of the intermediate cell mass. The rudiments of the fore- and hind-limbs are discernible, almost from the first, as slight prominences of the Wolffian ridges, and in the fourth week they project as bud-like outgrowths in the thoracic and pelvic regions respectively. The development of the fore-limb or arm is throughout slightly in advance of that of the hind-limb or leg. At the fourth week each limb-bud is a flattened semilunar projection, as long as it is broad, with a dorsal and a ventral surface and an anterior or preaxial, and a posterior or postaxial border. As growth proceeds the elongating limb-buds are bent ventrally, and in the fifth week two transverse furrows, on the ventral aspect of each, indicate the positions of the joints and the division of each limb into three segments—distal, middle, and proximal—representing the hand, fore-arm, and arm in the upper limb, and the foot, leg, and thigh in the lower limb. The terminal or distal segments are broad, flat plates with rounded margins, but each is soon divided into a somewhat enlarged basal part, and a thinner and more flattened marginal part. It is where these two parts are continuous that the rudiments of the digits appear. They become distinguishable about the end of the fifth week as small lobes which gradually extend outwards. In the fore-limb the fingers project beyond the margin of the hand-segments in the sixth week, but the toes do not reach the margins of

the foot till the early part of the seventh week. The nails appear at the third month, and reach the ends of the digits at the sixth month.

In the primary position of the limbs the elbow and the knee appear alike to be directed outwards, but this is soon altered. At the end of the sixth week each limb undergoes a partial rotation, the direction of which is different in the fore- and hind-limbs respectively. In the former the elbow is turned backwards, the ventral surface therefore becomes anterior, and the preaxial (thumb) margin is directed outwards; in the hind-limb the knee is turned forwards, and the ventral surface of the limb becomes posterior, whilst the preaxial (great toe) margin is directed inwards; thus in the adult the anterior surface and outer border of the upper extremity correspond with the posterior surface and inner border of the lower extremity, whilst obviously the posterior surface and inner border of the former are homologous with the anterior surface and outer border of the latter.

Each limb-bud may be regarded as an extension from a definite number of the segments of the body; it contains a core of mesoderm, and the anterior or ventral primary divisions of the corresponding spinal nerve segments are apparently prolonged into it.

The central part of the mesoderm, except in the regions of the joints where cavities appear, is condensed and then converted first into cartilage, and afterwards into bone. The proximal part of the bony skeleton of each limb, the limb girdle, is not, however, developed in the limb-bud, but in the body-wall at its base. The more superficially situated mesoderm is transformed into muscles and subcutaneous tissues, the extensor muscles appearing on the dorsal and the flexor muscles on the ventral aspect.

As the nerve trunks pass into the free portion of the limb they bifurcate, the branches passing respectively to the dorsal or extensor aspect of the limb, and to the ventral or flexor aspect.

Apparently in mammals the whole of the mesodermal core of each limb-bud is formed from the somatic mesoderm of the lateral plates. If this is the case the muscles of the limbs differ in origin from those of the back, for the latter are developed from the muscle plates of the protovertebral somites. In lower vertebrates (cartilaginous fishes) buds are given off to the limbs from the muscle plates and cutaneous lamellæ in the thoracic and pelvic regions, and as the muscle plates pass downwards in the somatopleure towards the ventral aspect of the body, these buds grow outwards into the limb-rudiments and develop into the muscles of the limbs. Presumably this is the more primitive arrangement, and that met with in man and other mammals is secondary, and it is stated that although no distinct buds from the muscle plates pass into the limbs of mammals, nevertheless the limb-muscles are formed by cells, proliferated from the muscle plates, which have migrated into the somatopleural mesoderm of the limbs.

THE NUTRITION AND PROTECTION OF THE EMBRYO DURING ITS INTRAUTERINE EXISTENCE.

The impregnated ovum during its passage down the Fallopian tube, and for a brief period also after it enters the uterus, lives either on the yolk granules (deutoplasm) embedded in its own cytoplasm, or upon material absorbed from the fluids by which it is surrounded. The human ovum is very small, and consequently it is almost from the first dependent for its nutrition upon sources of supply outside itself. The urgent necessity for adequate arrangements whereby this may be effected leads to that early establishment of an intimate vascular connexion between the embryo and the mother which is so characteristic a feature in the development of the human ovum. At the end of the second week, after fertilisation of the ovum, the embryo is separated by a slight constriction from the rest of the blastodermic vesicle, and already a primitive heart and rudimentary blood-vessels are distinguishable.

The development of the vascular system, and the establishment of the fœtal

circulation, however, cannot well be understood until the formation and structural features of the group of closely associated extra-embryonic organs or appendages have been considered.

This group includes the yolk-sac, the chorion, the amnion, the allantois, and the placenta.

THE FŒTAL MEMBRANES AND APPENDAGES.

Yolk-Sac or Umbilical Vesicle.—That portion of the blastodermic cavity and its wall which is not included in the body of the embryo to form the primitive alimentary canal constitutes the umbilical vesicle or yolk-sac. Its walls, like its cavity, are continuous with the corresponding parts of the intestine, and their structural features are identical, there being an inner layer of entodermal cells and an outer layer which is formed by the splanchnic layer of the mesoderm.

In the human embryo the yolk-sac is a small flask-like body, suspended from the ventral wall of the alimentary canal by a hollow stalk, the **vitello-intestinal duct**, which passes through the umbilical orifice. It lies in the extra-embryonic continuation of the body-cavity (cœlom), and is filled with fluid. Possibly the contents of the yolk-sac are utilised in the nutrition of the embryo in its earliest stages, and the first rudiments of the blood vascular system, viz. blood corpuscles and vessels, appear in its walls. In the human embryo, however, it is of little nutritional importance; it soon atrophies and almost entirely disappears, but leaves traces of its existence in the umbilical cord.

Amnion.—The amnion is a protective sac which surrounds the embryo. It is formed, after the development of the cœlom, from the amniotic area of the blastoderm, and its wall is continuous, at the margins of the umbilical orifice, with the body-wall of the embryo. Both walls consist of a layer of ectoderm and a layer of somatic mesoderm, but whilst in the body-wall the ectoderm is external and the mesoderm internal, the relative positions of the layers are reversed in the amnion, the mesoderm being external and the ectoderm internal.

The cavity enclosed between the amnion and the embryo, the **amniotic cavity**, is filled with fluid, the **amniotic fluid**, in which the embryo floats. The amniotic cavity is quite shut off for some time from all the neighbouring spaces, but after the disappearance of the bucco-pharyngeal and cloacal membranes it communicates, both anteriorly and posteriorly, with the alimentary canal of the embryo.

The development of the amnion in mammals is closely associated with the attachment of the ovum to the uterine wall and with the subsequent formation of the placenta. Thus in the carnivora, before the cœlom is formed, the ectoderm in the chorionic area becomes attached to the uterine tissues by small villous outgrowths which invade the uterine mucous membrane. This attachment is most complete in the placental region, that is, around the margins of the amniotic area. As the embryo is folded off from the blastoderm and the cœlom develops, both the embryo and the amniotic area remain quite free from the uterine tissues, indeed, it may be said that, at this period, the embryo is suspended from the margins of the placental area by the amniotic membrane.

As development proceeds the amniotic area increases in extent by interstitial growth, and thereupon the embryo, the membrane which suspends it being relaxed, sinks more and more into the interior of the ovum, or, to be more precise, into the cœlomic space, which, in the meantime, has considerably increased. At the same time the growth of the placental area causes all parts of its inner margin to converge, and as the inner margins of the placental area are continuous with the outer margins of the amniotic membrane, the amnion is gradually carried over the dorsal surface of the embryo till its margins meet and fuse. After the fusion of its margins the amnion separates entirely from the chorionic area, henceforth known as the chorion, and forms a closed sac which completely surrounds the embryo.

On reference to Figs. 21 and 27 it will be seen that as the wall of the blastodermic vesicle is carried inwards over the dorsal surface of the embryo it is folded; the outer part of the fold consists of the chorionic portion, and the inner part of the

amniotic portion of the blastoderm. The fold is called the **amnion fold**; it is quite continuous round the whole margin of the embryo, but some parts of it are more advanced than others, or in other words the convergence of the inner margin of the placental area of the blastoderm over the dorsal surface of the embryo does not take place at the same rate or to the same extent in all parts. For convenience of description it is usual to divide the amnion fold into four parts—the cephalic, the caudal, and the two lateral amnion folds; these, however, are all continuous with one another.

The inner part of the fold, which is formed from the amniotic area, is termed the **true amnion**, and the outer part, formed from the chorionic area, the **false amnion**. The latter term is, however, synonymous with chorion, and as it is misleading, it should be avoided.

As the amnion is formed from the amniotic area of the blastoderm after the extension of the cœlom, it must consist, as previously mentioned, of ectoderm and somatic mesoderm, and as the surface of the amniotic area is reversed during the formation of the amnion folds, it is obvious that in the fully-formed amnion the ectodermal layer is internal and the somatic mesoderm external.

In the case of the human ovum the phenomena of amnion formation are probably practically similar, except that the ovum develops not in the cavity of the uterus, but in the substance of the mucous membrane into which it has penetrated. It is therefore surrounded by the mucous membrane on all sides, and the chorionic part of the surface of the ovum is closely attached to the surrounding tissue, but the amniotic and embryonic areas are free. If this is the case the process of amnion folding can take place in the human ovum exactly as in the ovum of a carnivorous animal, the inner margin of the chorionic area growing inwards over the amniotic and embryonic areas, the only difference being that the process takes place in a cavity in the mucous membrane and not on its surface. This conclusion is supported by Spee's observations on human ova and by those of Selenka on the ova of monkeys and apes, but it is, however, possible that, as in some rodents and insectivora, the amnion cavity appears in a mass of ectoderm which lies at the embryonic pole of the ovum, the mass being cleft by the appearance of the cavity into embryonic and amniotic sections. The two parts are then continuous at the

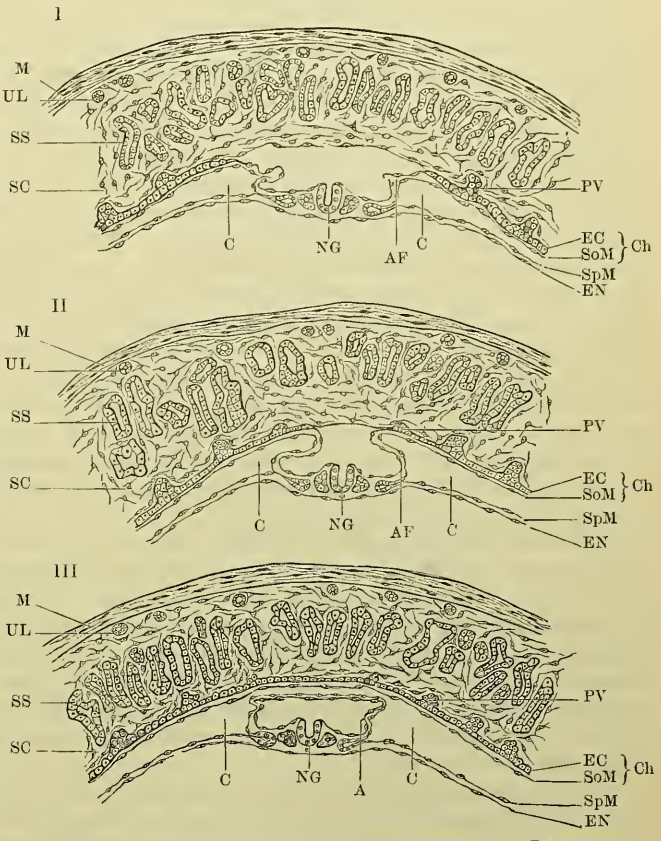


FIG. 38.—TRANSVERSE SECTIONS OF THE UTERUS AND DEVELOPING OVUM OF A FERRET.

Showing the formation and closure of the amnion folds, the completion of the amnion, and the coincident ingrowth of the inner margins of the placental area of the blastoderm.

A.	Amnion.	EN.	Entoderm.	SC.	Stratum compactum.
AF.	Amnion fold	M.	Muscular wall of uterus.	SS.	Stratum spongiosum.
C.	Cœlom.	NG.	Neural groove.	SoM.	Somatic mesoderm.
Ch.	Chorion.	PV.	Placental villus.	Sp.M.	Splanchnic mesoderm.
EC.	Ectoderm.			UL.	Unchanged layer of uterine mucosa.

margin of the embryonic area, and the mesoderm growing round the amniotic ectoderm separates it from the chorionic ectoderm.

After the amnion is completed its cavity is distended with fluid. As it expands it gradually obliterates the extra-embryonic part of the cœlomic cavity, and finally its outer surface, of somatic mesoderm, comes into contact and fuses with the somatic mesoderm on the inner surface of the chorion. At this period the cavities in the ovum are the amniotic cavity, the remains of the yolk-sac, and those portions of the original blastodermic and cœlomic spaces which have been included in the embryo.

In the human ovum, when the amnion folds unite and the true amnion separates from the chorion, the embryo and its enclosing amnion would be free within the cavity of the chorion, or extra-embryonic cœlom, were it not that a very short cord of somatic mesoderm and ectoderm, the body-stalk, connects the posterior end of the embryo with the somatic mesoderm on the inner surface of the chorion.

Body-Stalk.—To thoroughly understand how this union is effected in the human ovum, and to comprehend the nature of the body-stalk, it is necessary to refer to some striking peculiarities which are to be observed in the earlier stages in the development of the human embryo. When segmentation is completed, and the morula is converted into a blastula by the appearance of a cavity in its interior, the human ovum consists of an outer layer, the ectoderm, and an inner cell-mass (Figs. 12 and 39). The latter, however, which is attached to a small area of the ectoderm, does not, as in many mammals, extend itself by migration round the inner surface of that layer, and so transform the unilaminar into a bilaminar blastoderm and convert the cavity of the blastula into the blastodermic cavity. The sequence of events is different: a cavity or space appears in the inner cell-mass itself (Figs. 41, 42, and 44), and this expanding rapidly, is ultimately converted into the yolk-sac and the alimentary canal of the embryo; it corresponds, therefore, with the blastodermic cavity of other mammals.

Thus the entoderm, though derived from the inner cell-mass, never lines the inner surface of the ectoderm except in the embryonic area, for soon after the appearance of the cavity of the inner cell-mass the mesoderm grows rapidly from the primitive streak and extends, not in a single layer, as in the majority of mammals, but as two layers, one over the outer surface of the entoderm, the splanchnic layer, and the other, the somatic layer, over the inner surface of the ectoderm. The cavity of the blastula is thus ultimately enclosed between the somatic and splanchnic layers of the mesoderm, and so becomes converted into the cœlomic space (Fig. 42).

As the mesoderm extends, the several areas of the blastoderm are differentiated as in other mammals, but the embryonic and amniotic areas remain of relatively small size. The separation of the amnion from the chorion is effected at a very early period, before the folding off of the embryo has commenced, but the somatic mesoderm growing from the posterior end of the embryonic area still retains its connexion with the similar layer on the inner surface of the chorion, and it forms a short, and for a time a broad stalk which unites the embryo, and consequently the amnion and the blastodermic cavity, with which the embryo is connected, to the chorion (Fig. 42). In addition to forming a bond of union between the embryo and the chorion the mesodermal stalk conducts blood-vessels from the embryo to the chorion, and more especially to its placental part.

At an early period a pouch-like diverticulum projects from the posterior part of the entodermal sac. This is the **allantoic diverticulum**; it lies beneath the posterior part of the embryonic area, and the area is curved upon itself so that its convexity looks towards the entodermal sac, and its concavity towards the amnion.

After the embryonic area has increased in extent, and when the folding off of the embryo has commenced, the anterior end of the area and the posterior end of the primitive streak remain relatively stationary as in other mammals, the cephalic and caudal folds appear, and the curvature of the greater part of the area is reversed, but the most posterior part retains its original position, lying for a time parallel with the caudal fold; afterwards, however, it assumes a more horizontal position. This posterior section of the embryonic area contains the diverticular process of the entodermal sac which is called the allantois; it also contains the

blood-vessels, allantoic arteries and veins, which pass between the embryo and the placenta. It is in relation at first with the amnion, it appears to be entirely behind the embryo, and it is called the "body-stalk." At a later period, when the stalk of mesoderm—the allantoic stalk—which connects it with the inner surface of the chorion is elongated, this part of the embryonic area is reversed in position, its anterior end is carried forwards till it forms the posterior boundary of the umbilical orifice, and the area in question forms the ventral wall of the body from the umbilical to the genital region.

Allantois.—The allantois plays an important part in the formation of the placenta. It consists of two portions, an entodermic diverticulum from the ventral wall of the cloacal part of the hind-gut, and a mesodermal covering. The entodermic diverticulum appears in the human subject, before the hind-gut is defined, as a hollow blind protrusion from the blastodermic cavity; it extends behind the primitive streak into the mesoderm of the body-stalk, but as the folding off of the embryo proceeds, and the body-stalk is carried forward into the ventral wall of the embryo, the position of the diverticulum is altered, and ultimately, when the folding off is completed, it springs from the ventral part of the cloaca, runs forward to the umbilical orifice, and passing through it, projects for a short distance still invested with the mesodermal covering primarily obtained from the body-stalk. The ventral part of the cloaca is afterwards converted into the bladder, while the rectum is formed from the dorsal part.

The mesodermal sheath which surrounds the entodermic diverticulum extends beyond it to the inner surface of the chorion; the part which extends beyond the diverticulum is at first extremely short, indeed it is only recognisable as a layer of mesoderm uniting the body-stalk and chorion, but as development proceeds and the body-stalk is folded forward to form the ventral wall of the body of the embryo, posterior to the umbilicus, this portion of the mesoderm is elongated, and it forms the **allantoic stalk** by which the embryo retains its connexion with the chorion, and along which pass the allantoic or umbilical arteries to, and the corresponding veins from, the chorionic villi.

After the separation of the cloaca into bladder and rectum, that portion of the allantois which lies in the body of the embryo, between the apex of the bladder and the umbilical orifice, is gradually converted into a fibrous cord, the **urachus.** The entodermal diverticulum disappears, and after birth, when the placental circulation ceases, the umbilical arteries are transformed into fine fibrous strands. The remainder of the allantois which lies outside the body of the embryo, and which takes part in the formation of the umbilical cord and placenta, is separated from the embryo at birth.

Umbilical Cord.—The umbilical cord is essentially a mesodermal structure which connects the embryo with the placenta, serving as a passage for the allantoic vessels to and from the fœtal portion of the latter organ. It replaces, functionally, the body-stalk and the allantoic stalk, which were earlier provisions for the same purpose, and it is formed by the fusion of the allantoic stalk with part of the vitello-intestinal duct and the remains of the yolk-sac.

The vitello-intestinal duct is at first a relatively wide channel which connects the primitive gut with the yolk-sac; it passes through the umbilical orifice. In later stages, as the body-stalk is swung round into the ventral wall of the body, the allantoic stalk, which projects from the end of the body-stalk, is brought into close relation with the distal end of the vitello-intestinal duct and the remains of the yolk-sac; the mesodermal constituents of the three structures then fuse together, and the whole is surrounded by the expanding amnion. In this way the umbilical cord is formed. It includes, therefore, the allantoic stalk and its blood-vessels, together with the remains of the yolk-sac and its stalk, the vitello-intestinal duct, all of which are invested and bound together by the amnion.

The mesodermal core of the cord forms a fibro-mucoid tissue known as "Wharton's jelly," which consists of stellate and irregular cells embedded in a gelatinous matrix. The blood-vessels of the cord are situated in the core, and include two allantoic or umbilical arteries which run spirally round a single umbilical vein. The terminal portion of the allantoic diverticulum projects into

the embryonic end of the cord, and at first a loop of intestine protrudes into it for a short distance; the gut, however, soon recedes into the abdominal cavity.

The umbilical cord, which extends from the umbilical orifice to the centre of the placenta, is at first short and straight. As the amnion expands the length of the umbilical cord increases until, at the time of birth it measures, on an average, about 20 inches. This increase in the length of the cord allows the fœtus to float freely in the amniotic fluid, and prevents traction on the placenta.

After the middle of the second month the umbilical cord is twisted spirally, usually from right to left. It is suggested that this is due either to the great elongation of the allantoic arteries or to muscular movements of the fœtus, and it involves a rotation of the fœtus in the amniotic fluid.

Chorion.—The chorionic area, by far the largest of the areas into which the blastoderm is divisible, lies external to the amniotic area. In most mammals it consists at first of ectoderm and entoderm, but after the extension and cleavage of the mesoderm has taken place, it is formed by ectoderm and somatic mesoderm. In man, however, it consists in the earliest stages of ectoderm alone, but on the formation and extension of the mesoderm it also acquires an inner layer of somatic mesoderm. In all cases, therefore, it eventually consists of the same two layers.

The ectoderm of the chorionic area which immediately surrounds the amniotic area thickens to form the annular placental area, and in this way the chorionic area becomes divisible into placental and non-placental regions.

When the blastodermic vesicle enters the uterus numerous ectodermal villous processes grow from the surface of the chorionic area, both in its placental and non-placental parts, and attach themselves to the uterine mucous membrane. As already pointed out in the description of the formation of the amnion, the embryonic and amniotic areas do not become attached to the uterus, but remain free from it, whilst by the approximation and fusion of its inner margins, the rapidly growing ring-like placental area is converted into a disc which intervenes between the amnion and the uterine wall.

The chorionic area after the separation of the amnion is known as the chorion or chorionic membrane.

The chorion forms the outer wall of a vesicle, the chorionic vesicle, which is the modified remains of the blastodermic vesicle, and which contains the embryo, the yolk-sac, the amnion, and the allantois. It consists of an outer layer of ectoderm and an inner layer of somatic mesoderm.

The cavity of the chorion is the extra-embryonic portion of the cœlom. For a time it remains distinct, and is traversed by the allantoic stalk which unites the embryo to the inner or mesodermal layer of the placental area. The cavity is ultimately obliterated by the growth of the amnion, the latter sac expanding rapidly till its outer surface is in contact and intimately blended with the inner surface of the chorion.

Chorionic Villi. — The villous processes which begin to grow from the surface of the chorionic area before it is separated from the amnion continue to develop after the separation of the two membranes is completed. They penetrate the surrounding uterine tissues. At first each consists of ectoderm only, but a core of vascular mesoderm is soon acquired. The villi increase in size and in complexity also, but ultimately only those in the placental area persist and continue to grow; the remainder atrophy and disappear.

Thus the placental region of the chorion eventually constitutes the main bond of union between the ovum and the mother, and it forms the fœtal part of the placenta.

THE PLACENTA.

The placenta is the organ of fœtal nutrition and respiration.

In it the blood-vessels of the fœtus and those of the uterus are brought into such close relationship with one another that free interchanges readily take place between the blood of the mother and that of the fœtus. In the simplest form of placenta the fœtal villi are merely embedded in the maternal mucous membrane, and the relationship between fœtal and maternal blood is not very close. In other

forms, *e.g.* the human placenta, the relation of fœtal to maternal blood is much more intimate; this involves marked complications in the elements of the placenta, and its structure becomes correspondingly more complex. In all forms, however, the placenta consists of fœtal and maternal portions.

Before the impregnated ovum reaches the uterine cavity the mucous membrane of the uterus undergoes certain changes in preparation for its reception and reten-

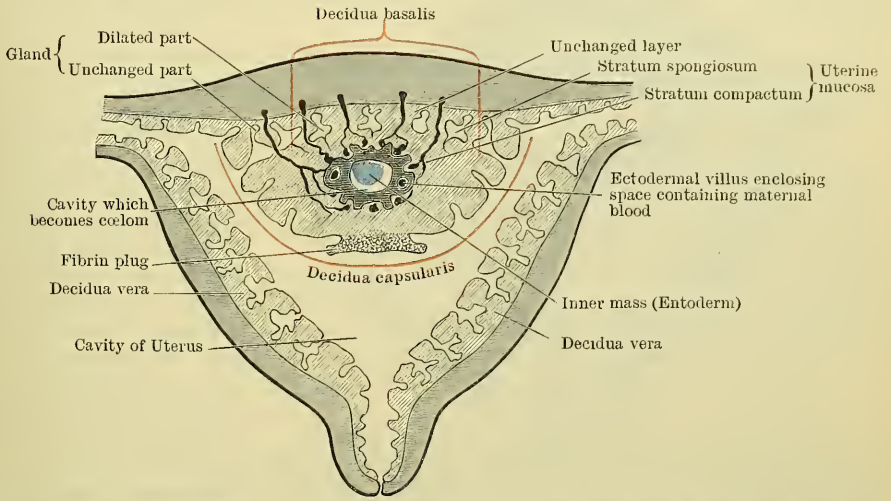


Fig. 39.—Diagram representing a very young human ovum almost immediately after its entrance into the decidua, and whilst the place of its entrance is still covered with a plug of fibrin. The ectoderm has already proliferated and embraced spaces which contain maternal blood and are continuous with the maternal blood-vessels.

tion, and the modified mucous membrane is known as the uterine decidua. These changes are, for the most part, hypertrophic; the vascularity of the mucous membrane is increased mainly by the dilatation of its veins and capillaries, the tubular uterine glands become elongated, irregular, and tortuous, and they dilate both at their orifices and in the deeper part of the mucous membrane; at the same time the interglandular connective tissue proliferates, and as a result the decidua is thicker, softer, and more spongy than the unaltered mucous membrane.

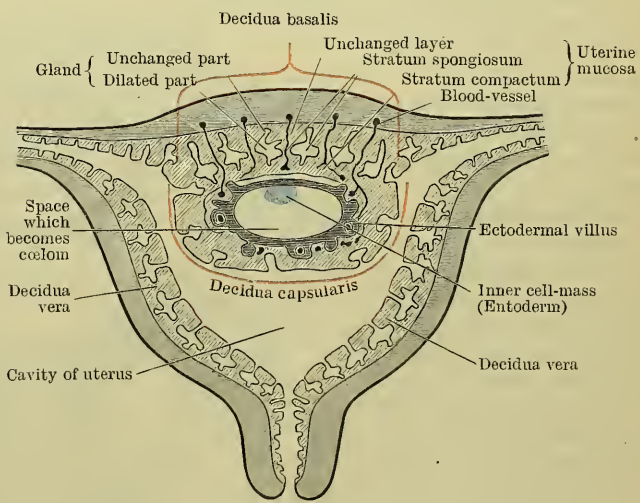


Fig. 40.—Diagram, showing the relation of the young human ovum to the decidua.

The ectoderm is distinct from the inner cell-mass, but as yet there is no entodermal cavity in the latter.

After the developing ovum enters the uterus it comes into contact with the decidua, into which it forces its way destroying the surface epithelium, and destroying, or pushing aside, the superficial portions of the glands. In this way it becomes embedded in the vascular interglandular tissue. The orifice which it makes in the superficial surface of the decidua is plugged, for a time, by a mass of fibrin, but all traces of the aperture which the fibrin closes eventually disappear and the ovum is entirely encapsuled in the decidua, which again presents an unbroken surface towards the uterine cavity.

Immediately after the ovum becomes embedded the superficial ectoderm cells of its surface proliferate rapidly and form numerous branching processes or villi which invade the surrounding decidua, destroying its cells and gradually enclosing the maternal blood spaces with which they come into relation. After a time the maternal tissues which at first surrounded the maternal blood spaces entirely disappear, and from this period onwards the maternal blood circulates in the spaces in the fœtal ectoderm. After a time the proliferation of the ectodermal villi becomes most marked immediately around the margin of the amniotic area of the ovum, and thus a placental area of the chorion is differentiated. In the meantime the expanding ovum has forced the decidua on its superficial surface towards the cavity of the uterus, and at this period three areas of the decidua can be distinguished. The part outside the ovum, that is between the ovum and the muscular wall of the uterus, is known as the **decidua basalis**; the part pushed into the cavity of the uterus around the growing ovum is the **decidua capsularis**; and the remainder of the decidua is the **decidua vera.**

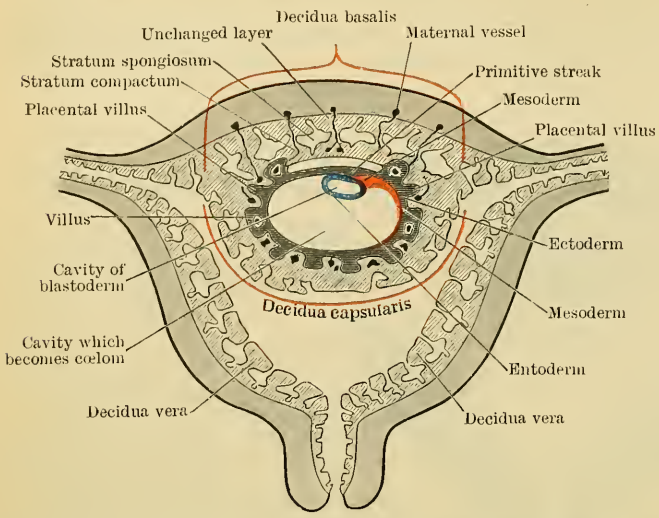


FIG. 41.—DIAGRAM, showing a further stage of development of the human ovum and its relation to the decidual tissues. The entodermal cavity or yolk-sac has appeared in the inner cell-mass, and the mesoderm has commenced to extend from the primitive streak in two layers, splanchnic on the yolk-sac and somatic on the ectoderm.

The **decidua capsularis** is not formed, as was formerly believed, by folds of the decidua which have grown up and surrounded an ovum merely attached to the surface of the decidua basalis. On the contrary it is merely the superficial part of that portion of the decidua into which the ovum has penetrated, therefore it may contain glands or the remains of glands which open on its superficial surface into the uterine cavity, but no glands open on its inner surface.

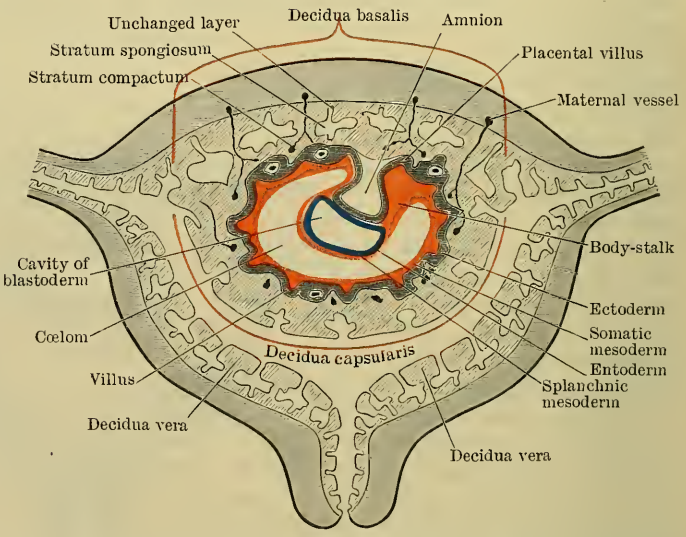


FIG. 42.—DIAGRAM, showing the completion of the decidua capsularis, the enlargement of the maternal blood-vessels in the stratum compactum of the decidua basalis, the increase of the placental villi, the formation of the amnion folds, and the appearance of the allantoic diverticulum.

The **decidua basalis** lies in contact with the placental area of the chorion, *i.e.* the fœtal part of the placenta, and it forms the maternal part of the organ. In the fully developed human placenta, the fœtal and maternal tissues of which it

is formed are so intimately mingled and blended together that it is impossible to say where one ends and the other begins. By a careful study, however, of a series of placentæ of different ages a fairly clear and satisfactory idea of the part played by the maternal and the fœtal elements respectively, as well as of their relations to each other, may be obtained. The structural characters of the completed organ will be best understood if the two constituent parts are first considered separately.

Fœtal Part of the Placenta. — The villi of the placental portion of the chorion invade and penetrate the decidua basalis, whilst the villi of the non-placental chorionic area of the ovum enter the decidua capsularis.

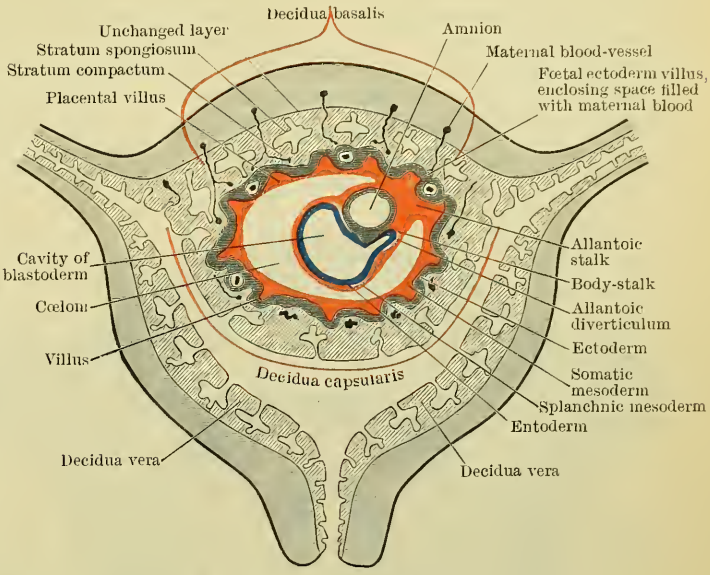


FIG. 43.—DIAGRAM, showing enlargement of the blood sinuses in the maternal part of the placenta and the closure of the amnion.

As previously explained, in connexion with the formation both of the amnion and of the chorion, the annular placental area is converted into a circular disc. It consists, like the rest of the chorion, of ectoderm and mesoderm, and it contains ramifications of the allantoic vessels; but the ectoderm is thickened and increased, its villi are larger than those of the non-placental region of the chorion, and it is directly connected with the allantoic stalk.

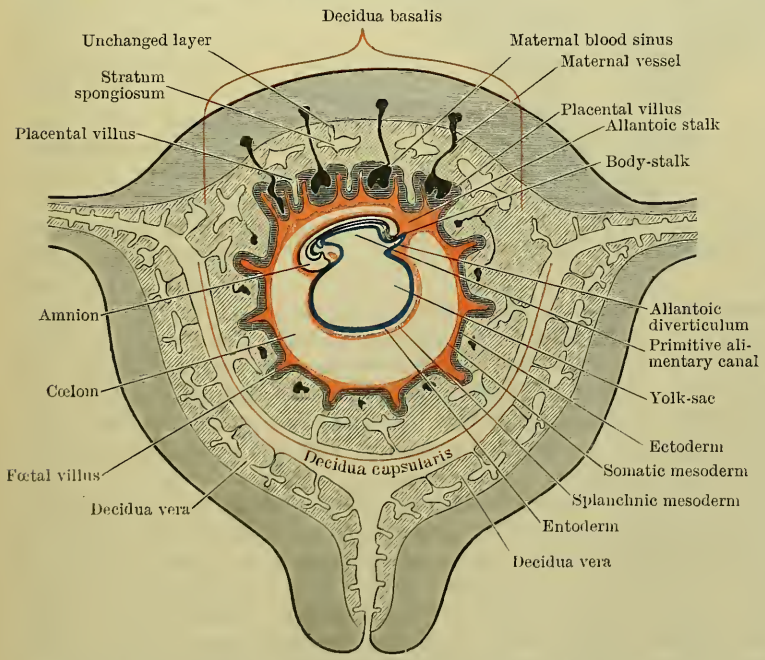


FIG. 44.—DIAGRAM, showing the fœtal ectoderm surrounding the maternal blood sinuses, the commencement of secondary fœtal villi which project into the sinuses, and the disappearance of the superficial portions of the glands.

The early villi are merely ectodermal buds which penetrate the surrounding decidual tissues, destroying and replacing the uterine elements. These villi grow and branch, and their branches anastomose together surrounding the blood spaces of the decidua which are in the immediate neighbourhood of the ovum. As development proceeds every ectodermal villus is penetrated by an outgrowth of the subjacent mesoderm

which carries branches of the allantoic vessels, and so the villi become vascularised with fœtal blood. For some time all the villi, placental and non-placental, grow and absorb nutriment from the maternal tissues, probably utilising as food the tissues which they destroy and replace; but when the decidua capsularis is thinned by the expansion of the growing ovum, the villi of the non-placental region which have penetrated it are no longer able to obtain nutrient matter, and they consequently atrophy and disappear. The placental villi, on the contrary, continue to increase; they grow in size and become more complex, and secondary branches growing from them project into the maternal blood spaces which they have surrounded and float in the maternal blood. When the formation of the placenta is completed, its fœtal part consists of villi, each of which possesses an external covering of two layers of ectodermal cells and a vascular mesodermal core; the villi project into the interior of large blood spaces which are surrounded more or less completely by fœtal ectoderm, and they are bathed by maternal blood from which they obtain the materials necessary for the nutrition and growth of the embryo, and into which they transmit the effete excretory matters from the embryo.

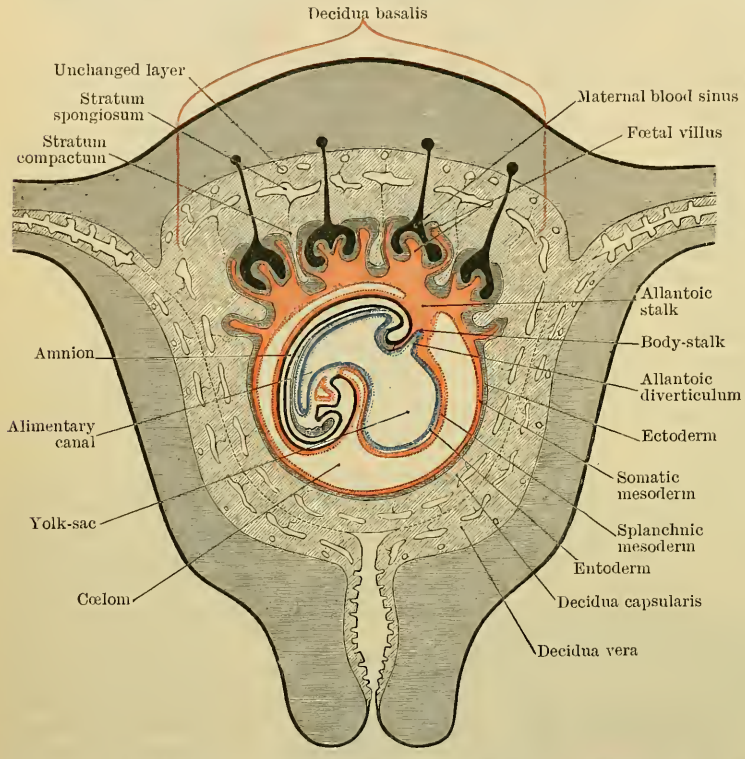


FIG. 45.—DIAGRAM, showing further growth of the placental sinuses and villi; the fusion of the decidua capsularis with the decidua vera, and the obliteration of the uterine cavity.

Maternal Part of the Placenta and the Changes in the Decidua.—The occurrence of further changes in the decidua, after the developing ovum enters the uterus, is dependent upon the retention of the ovum in the substance of the decidua. These changes only occur, therefore, in what may be termed the decidua of pregnancy. They are intimately associated with and essential to the development of the maternal part of the placenta, and a more detailed and complete account of the decidua and the modifications of its several parts is therefore necessary.

The **decidua** is formed by the mucous membrane of the uterus, which is a hollow, thick-walled muscular organ, situated in the pelvic cavity. The mucous membrane contains numerous tubular glands embedded in an interglandular tissue formed of round and irregular cells. The uterine glands are lined by a columnar or cubical epithelium, and they open into the cavity of the uterus on a surface which is also covered by columnar cells. The whole of the mucous membrane is plentifully supplied with blood-vessels which pass into it from the surrounding muscular walls, and it is transformed into the decidua by proliferation and hypertrophy of all its parts. The interglandular tissue increases in amount and its blood-vessels dilate, especially near the surface of the membrane; but the most striking of the early changes occur in the glands—they become longer, more tortuous, their

apertures enlarge and assume a funnel-like appearance, and they dilate a short distance from their terminations into large irregular spaces. The increase of the interglandular tissue is most marked in the intervals between the dilated portions of the glands and their apertures, and when all the changes are fully established it is possible to recognise three layers of the decidual tissue. (1) A superficial relatively thick layer in which the interglandular tissue preponderates, the **stratum compactum**; (2) A layer formed principally by the dilated portions of the glands, the **stratum spongiosum**; and (3) a thin deep part of the membrane which contains the outer extremities of the glands which are practically unchanged, the **unchanged layer.**

The decidua capsularis differs from the other portions of the decidua in that it represents only the superficial portion of the other parts of the decidua, and therefore contains no spongy layer or deep unchanged layer. This is obviously the case, for after the ovum has penetrated through the surface epithelium it becomes embedded in the stratum compactum of that portion of the decidua which it has invaded, and consequently the portion of the stratum which closes over it cannot contain more than the outer parts of some of the uterine glands with their orifices and the intervening interglandular tissue.

The changes which occur in the decidua capsularis are due, first, to its connexion with and invasion by the chorionic villi; and, secondly, to the pressure exerted upon it by the enlarging ovum. The former influence is brought to bear whilst the decidua is still increasing; the latter after it has reached its full development.

The changes which result from its union with the chorion are the destruction and absorption of some of the interglandular tissue; they are due to the activity of the ectodermic cells of the chorion, which attack and invade the uterine tissues.

The changes due to pressure exerted by the enlarging ovum are diminution of vascularity, disappearance of the lumina of such portions of the glands as remain in the decidua capsularis, and the removal of their epithelium, together with the coincident atrophy of the fœtal villi which have penetrated this portion of the placental decidua. All these changes result in the reduction of the decidua capsularis to a thin membrane in which no traces of the original structure are recognisable, in the fusion of the altered decidua capsularis with the decidua vera, and the consequent obliteration of the uterine cavity.

After the fifth month the decidua vera also undergoes atrophic changes, but they do not proceed so far as in the decidua capsularis; nevertheless the stratum compactum is greatly reduced, the superficial epithelium and the superficial parts of the glands entirely disappear from it, the interglandular tissue becomes less vascular, and it diminishes very considerably in thickness. The epithelium disappears from the spaces in the spongy layer, and the spaces themselves are flattened out into long slit-like clefts, in which condition they remain till the period of pregnancy is completed. The decidua vera is thus reduced to the condition of a relatively thin membrane, and its inner surface is fused with the remains of the decidua capsularis.

Decidua Basalis.—This portion of the decidua is constituted by the deeper part of the stratum compactum in which the ovum is embedded together with the more externally situated spongy and unchanged layers, and, apart from the changes due to the invasion of the fœtal villi, the most important transformations in this part of the decidua occur in the stratum compactum. The alterations in the spongy layer are similar to those which occur in the same layer of the decidua vera, viz. the lining epithelium disappears and the spaces are flattened out into a layer of cleft-like slits.

In the stratum compactum, however, much more striking changes occur; all traces of the glands disappear, but the blood-vessels become greatly dilated, and, consequently, the layer increases considerably in thickness. The small blood-vessels which lie in the immediate neighbourhood of the ovum become converted into enormous blood sinuses, but in the deeper part of the stratum a thin layer, which lies next the stratum spongiosum, remains relatively unchanged; this deeper part is called the **basal layer**, and through it the blood-vessels pass to and from the

blood sinuses in the more superficial portion of the membrane. When it is completed, therefore, the maternal portion of the placenta, which is the transformed decidua basalis, no longer consists of the stratum compactum, the stratum spongiosum, and the unchanged layer, but it is formed from within outwards of—(1) a layer of blood sinuses, (2) the basal layer, (3) the modified spongy layer, and (4) the unchanged layer. The difference between the decidua basalis and the maternal part of the placenta may be tabulated as follows :—

Decidua basalis.	Maternal placenta.
Deep part of stratum compactum	Layer of blood sinuses. Basal layer.
Stratum spongiosum	Modified stratum spongiosum.
Unchanged layer	Unchanged layer.

It must not be forgotten, however, that whilst the changes which result in the formation of the maternal placenta out of the decidua basalis are taking place the stratum compactum has been invaded by the placental villi.

The first result of this invasion is the destruction of much of the decidual tissue by the ectoderm of the fœtal villi. Gradually the ectoderm of the villi, always in advance of the main body, reaches and surrounds the dilated decidual vessels, destroys the intervening tissues, and ultimately replaces the endothelial walls of the vessels, which by this time have dilated into enormous spaces. Into these spaces the ramifications of the villi project, and, as the endothelial walls are destroyed, they lie directly within the cavities of the spaces, and are surrounded on all sides by maternal blood. The most peculiar feature of this part of the placenta, when fully developed, is that the whole of the maternal portion of it, except the blood, has been removed and replaced by fœtal tissues, so that, although the maternal blood continues to circulate in the same spaces which it has occupied from the first, viz. the blood sinuses in the more superficial part of the stratum compactum of the maternal decidua, yet the walls of these spaces have been replaced more or less

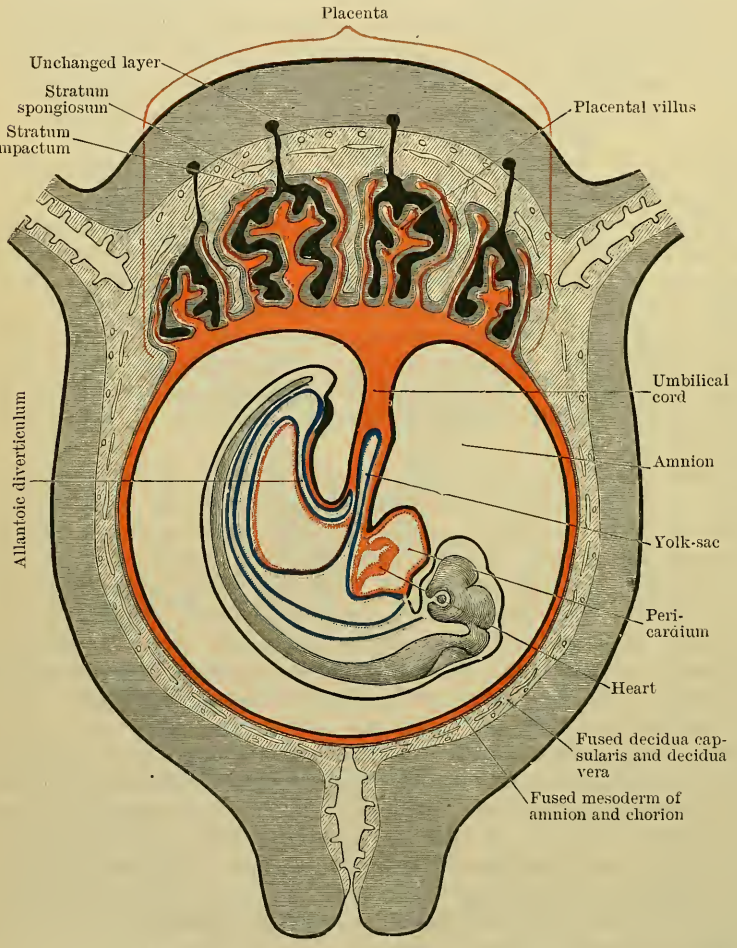


FIG. 46.—DIAGRAM. Later stage in the development of the placenta, showing the relations of the fœtal villi to the placental sinuses, the fusion of the amnion with the inner surface of the chorion, and the thinning of the fused deciduæ (capsularis and vera).

completely by fœtal ectoderm, and, consequently, the spaces now lie in the midst of the fœtal tissues.

The invasion of the maternal by the fœtal part of the placenta proceeds as far as the basal layer, and in this region the fœtal ectoderm is directly continuous with the walls of the maternal blood-vessels at the points where they enter the sinuses.

Although the invasion of the decidua basalis is so complete, some portions of the maternal tissues persist; thus the basal layer and many strands of the stratum compactum escape destruction. The latter extend from the basal layer to the outer surface of the chorion, and they are eventually converted into fibrous strands, which divide the superficial part of the completed placenta into lobular areas.

The **completed placenta** consists, therefore, of closely intermingled and fused fœtal and maternal tissues, through which both the fœtal and maternal blood streams circulate. It is well adapted, on account of its peculiarities of structure, to fulfil the nutritive and respiratory requirements of the embryo. The fœtal blood stream which flows through the placental villi and the maternal blood stream in the placental sinuses are only separated from each other by two layers of fœtal ectodermal epithelium and a small amount of fœtal mesoderm, the latter being practically reduced to the single layer of endothelial cells which form the walls of the fœtal vessels. Through these layers, by osmosis, and possibly by secretion, materials are passed both from mother to embryo and from embryo to mother, the placenta serving not only for purposes of nutrition and respiration, but also as an excretory organ.

Whilst the placenta is attaining its full development the amnion is expanding, and finally its outer surface fuses with the inner surface of the chorion, consequently, the innermost portion of the placenta is provided with a covering of amnion.

The full-time placenta is a discoid mass about 20 or 25 inches (50 to 60 cm.) in circumference and $1\frac{1}{4}$ in thickness at its centre; it is much thinner, however, at its margins, where it is continuous with the membranes formed by the fused chorion, decidua vera, and decidua capsularis. Its weight is about one pound, and it consists from within outwards of the following layers:—

Fœtal	Amnion	Ectoderm.
		Mesoderm.
	Allantois with fœtal vessels	Mesoderm.
	Chorion	Mesoderm.
		Ectoderm.
Maternal	Layer of maternal blood sinuses and remains of the interglandular tissue of the stratum compactum.	
	Basal layer.	
	Modified spongy layer.	
	Unchanged layer.	

When the period of intrauterine life is completed the muscular walls of the uterus contract and the lower orifice of the uterine cavity is dilated, the fused chorion and amnion, which close the upper part of the orifice, rupture and the amniotic fluid escapes, the fœtus is then expelled, but it remains attached to the placenta by the umbilical cord. The cord is divided artificially, and after a short period the placenta and membranes are expelled. The membranes attached to the placenta consist of the fused amnion, chorion, decidua capsularis, and also the decidua vera internal to the altered spongy layer; therefore both the placenta and the membranes consist of maternal and fœtal tissues. Before the placenta and membranes are expelled the uterine decidua is separated into two parts by a cleavage which takes place in the modified stratum spongiosum. The inner portion which includes the placenta and membranes is cast off. The outer portion remains in the uterus; it consists almost entirely of the deep unchanged layer of the decidua, and from it the uterine mucous membrane is reconstructed.

THE PRIMITIVE VASCULAR SYSTEM AND THE FŒTAL CIRCULATION.

It has already been said that the ovum during its passage down the Fallopian tube lives either on its own yolk particles or upon substances absorbed from the fluids by which it is surrounded. For a time after it enters the uterus its nutrition must be provided for in a similar manner, but as soon as the chorionic villi are formed it is probable that the ectodermal cells, of which in the earliest stages they entirely consist, and which cover their surfaces in the later stages, actually eat up the decidual tissues which they invade and use them for food. This source of nutrition, however, is only sufficient for the short period during which the ovum remains relatively small, and substances absorbed through the surface cells can be readily transmitted to all its parts.

In addition to the solid decidual tissues devoured by the ectodermal cells it is evident that fluids from the mother are also absorbed, for the yolk-sac and cœlom enlarge and are filled with fluid. The only sources from which this can have been derived are the uterine glands or the blood and lymph vessels of the decidua.

In all probability the fluids absorbed into the ovum contain nutritive material, and so long as the embryo is constituted by the thin layers of the early blastoderm sufficient food material can easily be absorbed. When, however, the various parts of the embryo increase in thickness and become moulded into the form of organs they are no longer in such intimate relation with the surrounding nutritive fluids, whilst, further, as their development progresses they require a greater amount of food and oxygen than they can obtain from these fluids. There is, therefore, an imperative necessity for a further supply of nutritive material by which their requirements may be satisfied, failing which, development must cease and death ensue.

To meet this necessity the vascular system is formed. It is essentially an irrigation system consisting of a propulsive organ, the heart, and of tubular vessels, the blood-vessels, all of which contain blood. The heart propels the blood through the blood-vessels to all parts of the embryo, but the blood which is at first formed from the mesoderm of the ovum must, at least so far as its fluid part is concerned, be supplemented largely from maternal sources. It is necessary, therefore, that the fœtal blood-vessels be brought into close relation with the maternal blood-vessels at an early period. It is for this purpose, amongst others, that the large blood sinuses are formed in the maternal portion of the placenta, and that they are surrounded and invaded by the fœtal villi, carrying in their interior branches of the fœtal blood-vessels, and as previously shown, the fœtal blood-vessels in the placenta are only separated from the maternal blood in the sinuses by their own thin mesodermal walls, and by one or two layers of ectodermal cells. When the placenta is fully formed fluids can readily pass from the maternal to the fœtal vessels, and there can be no doubt that both food and oxygen pass from the maternal blood to the fœtal blood through and by the agency of the intervening cells, whilst at the same time the waste products which are formed in the embryo pass outwards to the maternal blood.

Obviously, however, a system of vessels filled with fluid would be of little use in the general economy unless there were some means by which the fluid could be kept in constant movement. In the first instance this is accomplished by rhythmical contractions of the vessel walls, but in a short time portions of the two primitive stem-vessels which appear in the embryo are modified into a single propulsive organ, the heart, which forces the fluid, or blood, in a definite direction both through the body of the embryo, along the body-stalk or umbilical cord, according to the age of the embryo, and through the vessels in the placental villi.

We have now to consider how the blood-vessels and blood are formed.

Where, or how, the first blood-vessels appear in the human subject is not definitely known, but in other mammals they are first seen outside the body of the embryo in the wall of the yolk-sac. The outer layer of the wall of the yolk-sac consists of splanchnic mesoderm, and in that part of this layer which lies nearest the primitive alimentary canal a large number of the cells proliferate

rapidly and, fusing together, form multi-nucleated masses of protoplasm, the "**blood islands**" of Pander.

Soon after their appearance the blood islands anastomose together by means of nucleated processes which they throw out on all sides, and thus a nucleated protoplasmic reticulum is formed in the substance of the splanchnic mesoderm. The region in which this occurs is known as the **vascular area**. The solid nucleated reticulum is soon converted into a system of anastomosing canals, the primitive blood-vessels, by the appearance within it of numerous vacuoles which soon fuse together, whilst at the same time the nucleated protoplasm is transformed into cells. The cells which lie nearest the interior separate from each other and form the primitive blood-corpuscles, whilst those situated externally remain connected by their margins and form the endothelial walls of the embryonic vessels. The fluid which fills these first-formed vessels in the vascular area is probably derived either from the cœlom or from the yolk-sac.

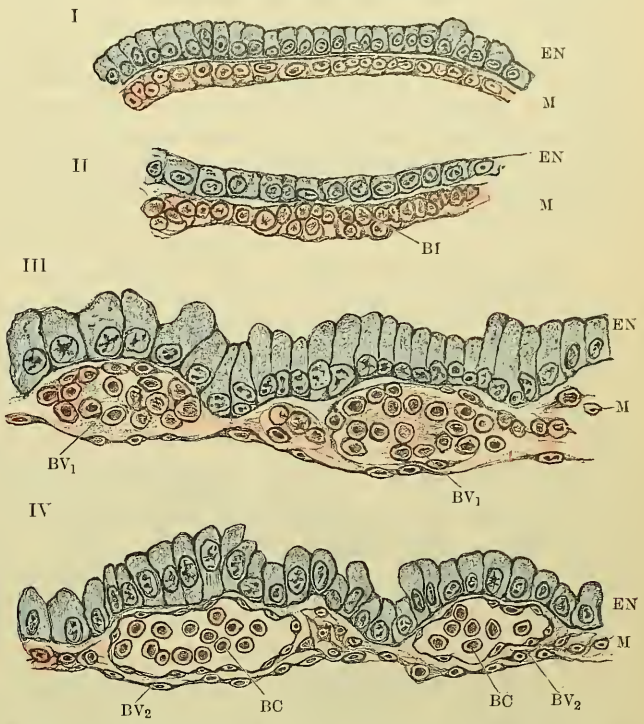


Fig. 47.—Development of Blood-Vessels in the Vascular Area of the Rat.

I. Entoderm and splanchnic mesoderm.
II. Proliferation of cells of mesoderm and formation of "blood islands."
III. Commencing differentiation of islands to form blood-vessels and blood-corpuscles.
IV. Completed vessels.

BC Blood-corpuscles.	BV_2 Blood-vessels.
BI Blood islands.	
BV_1 Blood islands being transformed into blood-vessels.	EN Entoderm. M Mesoderm.

The primitive blood-corpuscles are nucleated cells of a reddish colour; white or colourless blood-corpuscles appear later, and it is stated that those first formed are developed in the thymus gland.

Nucleated red corpuscles persist and increase in number till the end of the second month of intrauterine life; they are then gradually replaced by non-nucleated red corpuscles. The majority of the nucleated red corpuscles disappear long before birth, but a few can usually be found in the blood of the new-born child. There is some doubt about their ultimate fate, but it is generally believed that their nuclei disappear, and that they are converted into non-nucleated corpuscles.

Directly after the appearance of the blood islands in the vascular area of the yolk-sac, and just as the folding off of the embryo commences, two short tubular vessels appear in the splanchnic layer of the pericardial mesoderm. These vessels at once extend forwards and outwards into the extra-embryonic region where they become connected with the vessels of the vascular area; they also extend backwards in the body of the embryo beneath the protovertebral somites. In the majority of mammals they at first terminate behind, as in front, on the wall of the yolk-sac, but after a time the main stems appear to be continued along the allantoic stalk to the placenta, whilst they give off branches to the yolk-sac. It is probable that in the human embryo also, though this has not apparently been actually observed, these main stem vessels, the primitive aortæ, end at first on the wall of

the yolk-sac, but on the fourteenth day of intrauterine life, before the heart is formed, the two primitive stem vessels pass backwards along the body-stalk to the chorion, their terminal branches entering the chorionic villi. As they pass backwards the primitive aortæ give off branches to the wall of the yolk-sac. Thus, at this period the vascular system of the human embryo consists of two longitudinal vessels which run parallel with each other, one on each side of the middle line, throughout the whole length of the embryo. They communicate anteriorly with the vessels on the yolk-sac, and terminate posteriorly in the chorion. When the circulation commences the blood flows from the anterior part of the vascular area into the anterior ends of the primitive aortæ, and passes backwards through the embryo. Some of it is returned to the vascular area by the branches which are given off to the walls of the yolk-sac; but the greater part is carried to the chorion, whence it returns by venous channels, the allantoic veins, which have been developed in the meantime, to the anterior ends of the primitive aortæ.

As the cephalic and caudal folds are developed the anterior and posterior parts of the primitive aortæ are carried into the ventral wall of the body of the embryo, and thus each primitive vessel is divisible into three parts: (1) a dorsal part, the primitive dorsal aorta, which extends from the dorsal end of the mandibular arch to the cloaca, and runs beneath the protovertebral somites; (2) an anterior ventral part, situated in the dorsal wall of the pericardium and extending from the umbilicus to the ventral end of the mandibular arch; and (3) a posterior ventral part, which at first runs in the ventral wall at the side of the cloaca, and then turns backwards in the body-stalk to the placenta, but afterwards, when the posterior part of the ventral wall of the body is completed, it extends forwards from the pelvic region to the umbilical orifice, through which it passes to the umbilical cord.

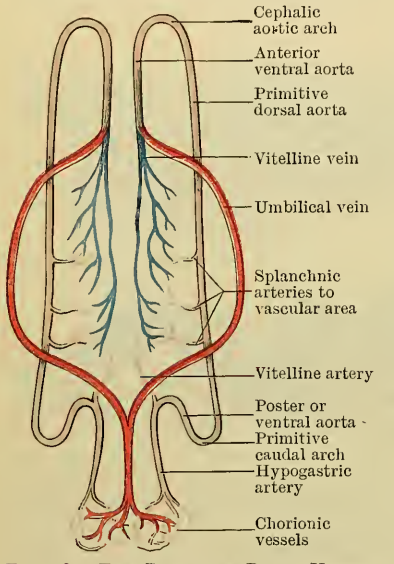


Fig. 48.—The Primitive Blood-Vessels of the Embryo.

The three sections are united together by two arches—an anterior arch, the first cephalic aortic arch, which passes through the mandibular arch, and a posterior arch, the caudal arch, which lies at the side of the cloaca.

In a short time four additional communications are formed between the anterior ventral and the dorsal part of each primitive aorta; they are the second, third, fourth, and fifth cephalic aortic arches, each of which lies in the substance of the corresponding visceral arch.

As soon as the last cephalic aortic arch is developed the rudiments of the main vessels of the embryo are established; and by a series of transformations, for a full account of which the chapter which deals with the Vascular System must be consulted, there are formed from the vessels which have been mentioned the heart, the aorta, the main vessels of the head and neck, the pulmonary artery and its primary branches, the common and internal iliac arteries, and the hypogastric arteries.

The blood distributed by the various arteries is returned to the heart by vessels called veins, which are developed in the substance of the mesoderm in the same manner as the arteries. From the yolk-sac the blood returns by the vitelline veins; from the alimentary canal and its appendages, through the portal and hepatic veins; from the head and neck, by the jugular veins and the superior vena cava; and from the body and lower limbs, first by the cardinal veins, and afterwards by the inferior vena cava and the azygos veins.

The heart is formed by the fusion of portions of the anterior ventral sections of the primitive aortæ behind the origins of the cephalic aortic arches, and, therefore, it is primitively a bilateral organ. Subsequently it possesses for a time a single chamber, but this is afterwards divided. During the greater part of fœtal life the

heart, as in the adult, possesses four chambers—two auricles or upper chambers, and two ventricles or lower chambers, right and left. The two auricles communicate with the corresponding ventricles through auriculo-ventricular apertures, and with each other through a foramen, the foramen ovale, in the septum between them.

In the adult the blood enters the right auricle by the superior and inferior venæ cavæ and the coronary sinus; from the right auricle it passes into the right ventricle, by which it is propelled through the pulmonary arteries and lungs; returning to the heart by the pulmonary veins it passes into the left auricle, and then into the left ventricle, by the contraction of which it is forced into the systemic aorta. From the aorta, by various branches, it traverses the organs and tissues of the body, and is returned again to the right auricle.

The course of the fœtal circulation differs from that of the adult; the blood passes out of the body into the placenta, to be oxygenated and purified, the lungs of the fœtus remaining functionless until the time of birth. Very little of the blood which is ejected from the right ventricle at every contraction of that chamber reaches the lungs; the greater part is transferred from the pulmonary

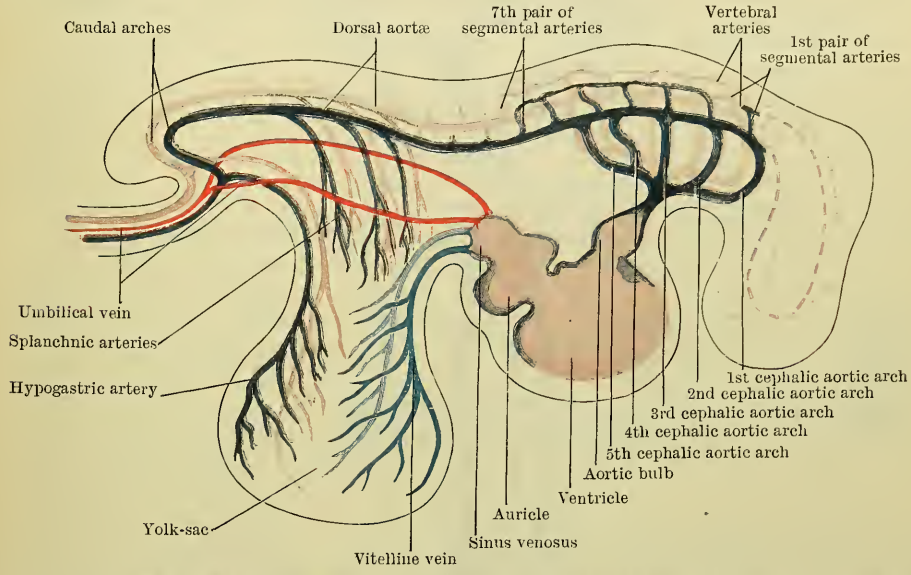


FIG. 49.—DIAGRAM OF THE BLOOD-VESSELS OF A MAMMALIAN EMBRYO AFTER THE FORMATION OF THE HEART.

artery to the aorta by an anastomosing channel, the ductus arteriosus, which disappears after the pulmonary circulation is established.

During the later months of fœtal life, blood enters the right auricle by the superior and inferior venæ cavæ and through the coronary sinus; only a small amount of blood, viz. that returning from the walls of the heart, enters the right auricle through the coronary sinus. The blood poured into the right auricle by the superior vena cava is returned from the head, neck, upper extremities, and the thoracic walls; passing from the auricle by the right auriculo-ventricular opening it enters the right ventricle; from the right ventricle it is forced into the pulmonary artery, and a small part of it traverses the lungs and returns to the left auricle by the pulmonary veins; the main part, however, is conducted by the ductus arteriosus into the aorta at a point beyond where the main vessel of supply to the left upper extremity, the left subclavian artery, rises.

The blood which enters the right auricle by the inferior vena cava is mixed; it consists partly of purified blood from the placenta, and partly of impure blood returning from the abdomen and lower extremities. The blood from the placenta is returned to the embryo by the umbilical vein. From the umbilical vein it passes along a channel called the ductus venosus, which terminates in the upper part of the inferior vena cava. The mixed blood from the inferior vena cava passes through the right auricle, traverses the foramen ovale in the interauricular septum, and

enters the left auricle; from the left auricle it is transferred to the left ventricle through the left auriculo-ventricular opening, and the left ventricle ejects it into the aorta. From the first part of the aorta some of the blood passes into the vessels which supply the head and neck and upper extremities, the remainder

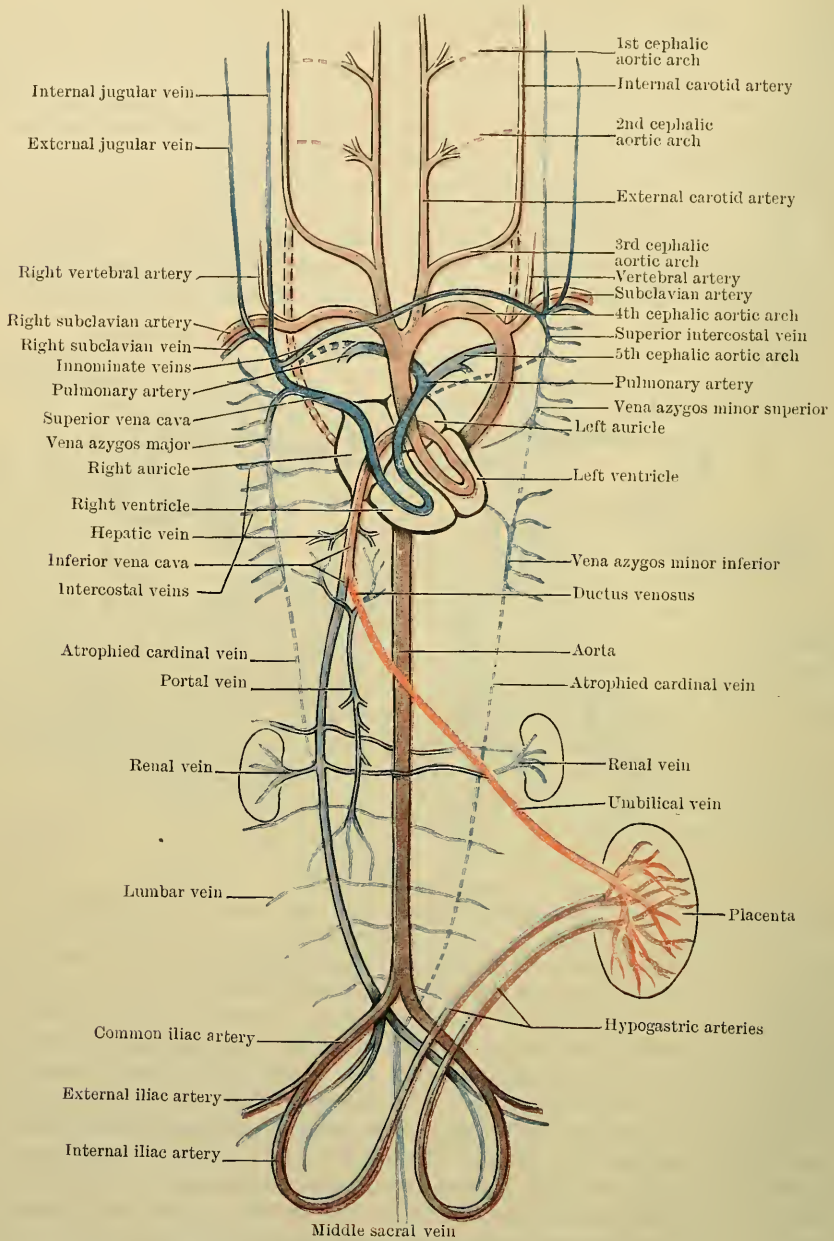


FIG. 50.—DIAGRAM OF THE FŒTAL CIRCULATION.

mixes with the blood conveyed to the aorta by the ductus arteriosus, and the blood, thus further mixed, is in part distributed to the walls of the thorax and abdomen to the abdominal viscera and to the lower extremities, and in part it passes to the placenta.

Before birth, therefore, there is no pure arterial or fully oxygenated blood in the arteries of the fœtus. The blood entering the heart by the superior vena cava is venous blood from the head, neck, upper extremities, and thorax; that entering by the inferior vena cava is mixed blood, consisting of venous blood from the lower

part of the body and the lower extremities, and arterial blood from the placenta. The two streams do not mix in the right auricle, but the mixed or more arterial stream passes directly through the right into the left auricle, thence into the left ventricle, and from the left ventricle into the aorta or main systemic vessel, which conveys it to all parts of the body. The different parts of the body do not, however, receive equally oxygenated blood, for the venous stream which enters the right auricle by the superior vena cava, passes through that cavity into the right ventricle; by the right ventricle it is forced into the pulmonary artery, from which some small part passes into the lungs, and so back to the left auricle by the pulmonary veins, but by far the greater part is carried by the ductus arteriosus to the aorta, which it enters beyond the origins of the vessels which supply the head, neck, and upper extremities; therefore the blood in the lower part of the aorta, which is distributed to the abdomen, the abdominal viscera including the liver, the lower limbs, and the placenta, is much more mixed or impure (less oxygenated) than that which is distributed to the head, neck, and upper extremities from the upper part of the aorta.

SUMMARY OF THE EXTERNAL FEATURES OF THE HUMAN EMBRYO AT DIFFERENT PERIODS OF DEVELOPMENT.

First week.—The phenomena of fertilisation and segmentation have not been observed in the human ovum, but there is no reason to believe that they differ in any essential respect from those met with in the ova of other mammals. Fertilisation probably occurs in the upper part of the Fallopian tube, and segmentation is completed in the lower part of the same canal by the sixth or eighth day, when, presumably, the ovum becomes a morula, and passes, either as such or as a blastula, into the cavity of the uterus.

Second week.—At the **twelfth day** the ovum is embedded in the uterine wall; it is a lenticular vesicle, which measures 5·5 mm. ($\frac{1}{5}$ of an inch) in length and 3·3 mm. ($\frac{1}{8}$ of an inch) in breadth. Its upper and lower surfaces are smooth and convex, the latter being somewhat flatter than the former, and it is surrounded equatorially by a broad band of villi, some of which are slightly branched. The wall of the vesicle and the villous processes which project from it consist of ectodermal cells, and in the embryonic area, which is clearly marked on the upper surface, there is an inner layer of granular nucleated corpuscles.

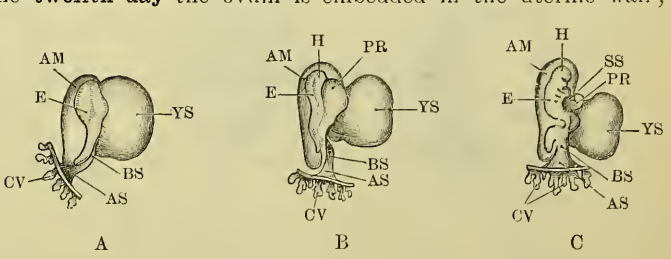


Fig. 51.

A. Human embryo at the end of the 12th day of development; B. At the end of the 13th day of development; C. At the end of the 14th day of development. (After His.)

AM. Amnion; AS. Allantoic stalk; BS. Body-stalk; CV. Chorionic villi on a segment of the chorion; E. Embryo; H. Head of embryo; PR. Pericardial region; SS. Stomatodæal depression; YS. Yolk-sac.

By the end of the twelfth or the beginning of the thirteenth day the length of the ovum has increased to 6 mm. ($\frac{1}{4}$ inch), and its breadth to 4·5 mm. ($\frac{1}{6}$ inch). The embryonic area is no longer on the surface of the ovum, for the amnion folds have closed. The yolk-sac is formed, and the rudiment of the allantoic duct projects backwards from the upper and posterior part of the embryonic area. Mesoderm has formed, and it has extended round the yolk-sac and over the inner surface of the chorion. The embryonic area, with the yolk-sac and the amnion, are enclosed within the blastoderm, but they remain attached to the inner surface of the chorion by a relatively thick stalk of ectodermal and mesodermal tissue, the body-stalk, which is subsequently replaced by the umbilical cord. The outer surface of the ovum, which now consists entirely of chorion, is covered with small villi into some of which mesodermal cores are projecting.

Obviously the ovum of the latter part of the twelfth day differs considerably from that of the earlier part of the same day, but the transitional stages which intervene between the two have not yet been observed. Probably, however, the inner granular layer of cells in the embryonic area, which represent the entoderm, increase and form a solid mass in which a cavity soon appears. Directly after the formation of the cavity in the entoderm the primitive streak appears, and the mesoderm, growing from it, rapidly

covers the entodermal sac and spreads over the inner surface of the chorionic area. At the same time the amniotic folds form and separate from the chorion, but this separation is not effected till the mesoderm, extending backwards from the posterior end of the embryonic area, has reached and becomes connected with the inner surface of the chorion. Consequently, when the amniotic folds fuse together and separate from the remainder of the blastoderm, the embryonic area with the yolk-sac and amnion still remain attached to the inner surface of the chorion.

During the **thirteenth day** the embryonic area is elevated, the cephalic and caudal folds are developed, and the pericardial region becomes prominent between the head extremity of the embryo and the upper and anterior part of the yolk-sac. The neural groove and the neural folds appear; the posterior ends of the folds embrace the anterior extremity of the primitive streak on which the primitive groove is formed. At the anterior end of the primitive groove a neurenteric canal appears, forming a communication between the neural groove and the posterior end of the primitive alimentary canal

On the **fourteenth day** the embryo is more distinctly separated from the yolk-sac; the head increases considerably in size, and its anterior part is bent downwards. The posterior part of the neural canal is completed, except at the extreme end, by the meeting and fusion of the neural folds, but it is still open anteriorly, where traces of the cerebral vesicles are present. The two halves of the heart fuse together; the single tube thus formed is slightly bent upon itself, and its outline is visible from the exterior. The pericardial region increases in size, and a distinct stomatodæal space appears between it and the anterior part of the head. The outlines of fourteen protovertebral somites are visible on the outer surface of the body.

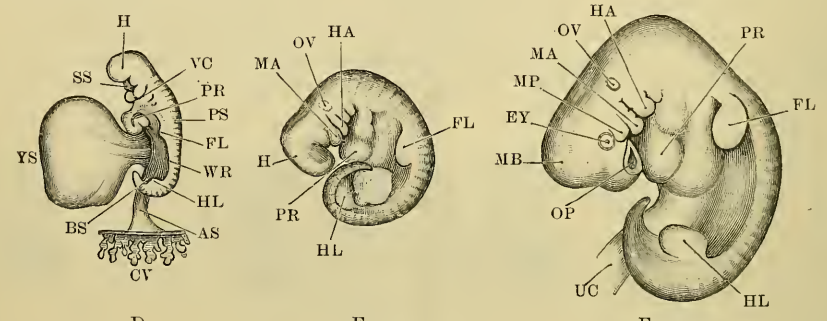


Fig. 52.

D. Human embryo at the 21st day of development; E. At the 23rd day of development; F. At the 27th day of development. (After His.)

AS. Allantoic stalk; BS. Body-stalk; CV. Chorionic villi on a segment of the chorion; EY. Eye; FL. Fore-limb; H. Head; HA. Hyoid arch; HL. Hind-limb; MA. Mandibular arch; MB. Mid-brain; MP. Maxillary process; OP. Olfactory pit; OV. Otic vesicle; PR. Pericardial region; PS. Protovertebral somite; SS. Stomatodæal space; UC. Umbilical cord; VC. Visceral cleft; WR. Wolffian ridge; YS. Yolk-sac.

Third week.—On the **fifteenth day** the auditory pits and two visceral clefts appear. The head and pericardial region enlarge, and the stomatodæal space, which increases simultaneously, becomes more defined laterally by the forward growth of the maxillary processes.

By the end of the third week Wolffian ridges appear below the ventral ends of the protovertebral somites; they are most marked in the thoracic and pelvic regions, where bud-like projections form the rudiments of the limbs. Four visceral clefts are visible, and there is a distinct tail.

Fourth week.—The embryo is curved upon itself, and its outline is almost circular. The visceral arches begin to overlap each other. The rudiments of the external ear are just visible as small nodules. The limb rudiments are flat, oval buds.

Fifth week.—The curvature is diminished, and the head and neck form about half the embryo. The eye is recognisable externally. The nose begins to grow forwards, but it is still broad and flat, and the nostrils are widely apart. The nodular elements of the external ear fuse together. The segments of the limbs are defined, but the digits do not project beyond the ends of the limb-buds. The genital tubercle, the rudiment of the external generative organs, is formed.

Sixth week.—During the sixth week the increase in size is less rapid than in previous stages, but the embryo begins to assume a more distinctly human form. The

head remains relatively large and it is bent at right angles to the body. The neck is better defined and appears as a constricted region between the head and trunk. The

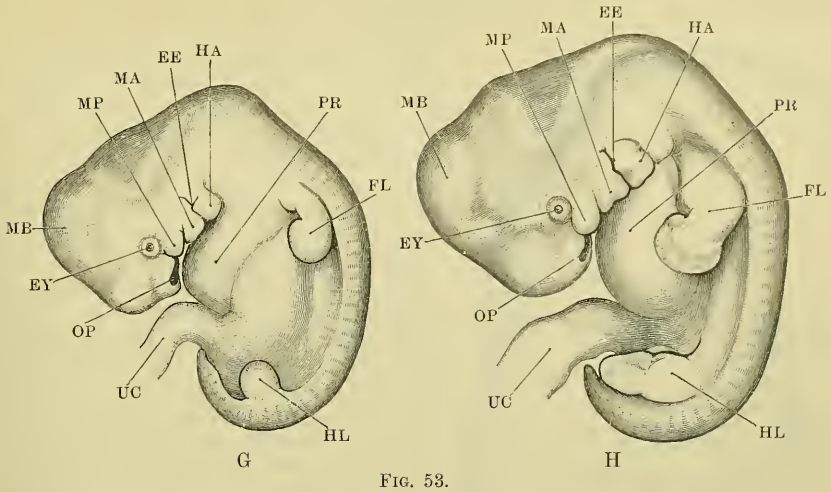


FIG. 53.

G. Human embryo at the 29th day of development ; H. At the 32nd day of development. (After His.)
EE. Rudiment of ear ; EY. Eye ; FL. Fore-limb ; HA. Hyoid arch ; HL. Hind-limb ; MA. Mandibular arch ; MB. Mid-brain ; MP. Maxillary process ; OP. Olfactory pit ; PR. Pericardial region ; UC. Umbilical cord.

maxillary processes fuse with the lateral nasal processes, and the lips and eyelids begin to assume their characteristic form. The outer parts of all the visceral clefts except the hyo-mandibular disappear. The external ear acquires its adult form. The rotation of

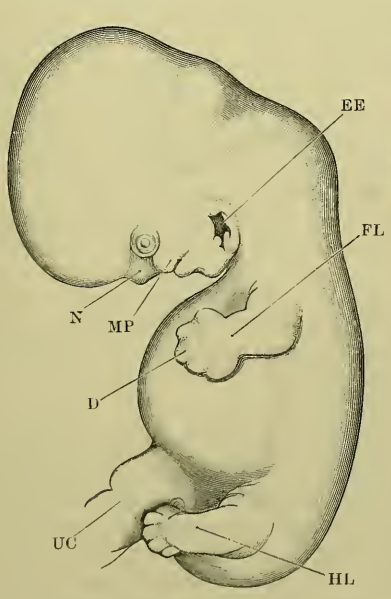


FIG. 54.—HUMAN FŒTUS AT THE SIXTH WEEK OF DEVELOPMENT. (After His.)

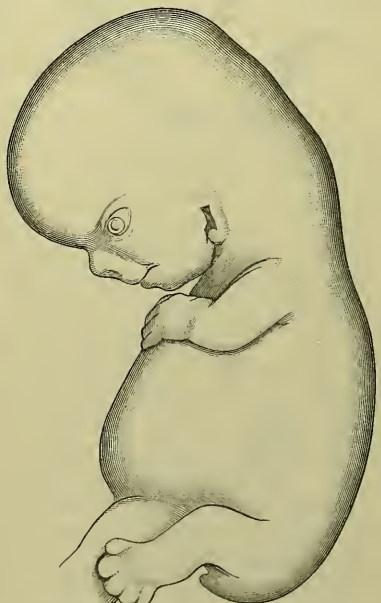


FIG. 55.—HUMAN FŒTUS SIX AND A HALF WEEKS OLD. (After His.)

D. Digits ; EE. Rudiment of ear ; FL. Fore-limb ; HL. Hind-limb ; MP. Maxillary process ; N. Nose ; UC. Umbilical cord.

the limbs commences, and the fingers reach the extremity of the hand ; the tail is beginning to disappear as an external projection.

Seventh week.—The flexure of the head upon the body is reduced. The nose projects more than in the preceding stage, and the chin appears. The toes reach the margins of the feet, and the projecting portion of the tail is still further reduced in length.

Eighth week.—The flexure of the head disappears. The forehead projects.

The nose narrows and becomes more prominent, but the anterior nasal orifices are still directed forwards. The upper lip is completed by the fusion of the globular processes. The thumb is widely separated from the fingers, and the hand assumes a distinctly human appearance. The tail is reduced to a small nodule, and the umbilical cord is attached to the lower part of the abdominal wall. At the end of the second month the total length of the fœtus, excluding the legs, is 28 mm. ($1\frac{1}{8}$ in.).

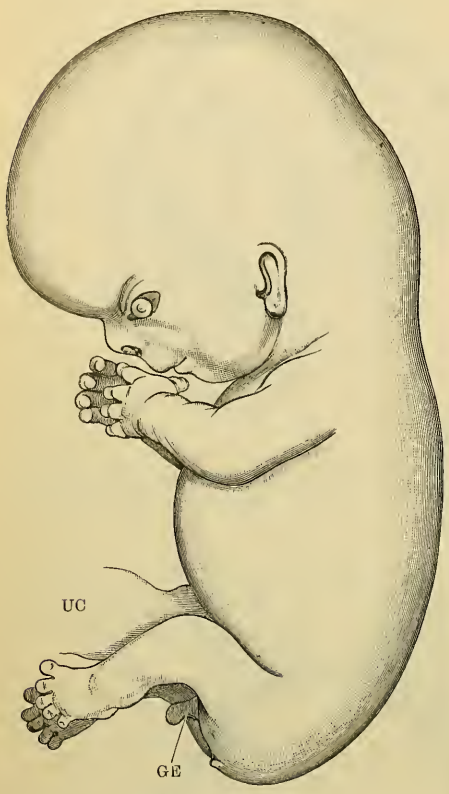


Fig. 56.—Human Fœtus eight and a half weeks old. (After His.)

GE. Genital eminence ; UC. Umbilical cord.

Third month. — The head grows less rapidly and, though it is still large, it is relatively smaller in proportion to the whole body. The eyelids close, and their margins fuse together. The neck increases in length. The various parts of the limbs assume their definite proportions, and nails appear on the fingers and toes. The proctodæum is formed and the external generative organs are differentiated, so that the sex can be distinguished on external examination. The skin is a rosy colour, thin and delicate, but more consistent than in the preceding stages. By the end of the third month the total length of the fœtus, excluding the legs, is 7 cm. ($2\frac{4}{5}$ in.), including the legs, 9-10 cm. ($3\frac{3}{5}$-4 in.), and it weighs from 100-125 grammes ($3\frac{1}{2}$-$4\frac{1}{2}$ oz.).

Fourth month. — In the fourth month the skin becomes firmer, and fine hairs are developed. The disproportion between the fore and hind limbs disappears. If the fœtus is born at this period it may live for a few hours. Its total length from vertex to heels is 16-20 cm. ($6\frac{2}{5}$-8 in.), from vertex to coccyx 12-13 cm. ($4\frac{4}{5}$-$5\frac{1}{5}$ in.), and it weighs from 230-260 grammes ($8\frac{1}{8}$-$9\frac{1}{5}$ oz.).

Fifth month.—The skin becomes firmer, the hairs are more developed, and sebaceous matter appears on the surface of the body. The legs are longer than the arms, and the umbilicus is farther from the pubis. At the end of the month the total length of the fœtus, from vertex to heels, is 25-27 cm. (10-$10\frac{4}{5}$ in.), from vertex to coccyx 20 cm. (8 in.), and its average weight is about half a kilogramme ($1\frac{1}{10}$ lbs.).

Sixth month.—The skin is wrinkled and of a dirty reddish colour. The hairs are stronger and darker. The deposit of sebaceous matter is greater, especially in the axillæ and groins. The eyelashes and eyebrows appear. At the end of the month the total length of the fœtus, from vertex to heels, is from 30-32 cm. (12-$12\frac{2}{5}$ in.), and its average weight is about one kilogramme ($2\frac{1}{5}$ lbs.).

Seventh month. — The skin is still a dirty red colour, but it is lighter than in the previous month. The body is more plump on account of a greater deposit of subcutaneous fat. The eyelids reopen, and the fœtus is capable of living if born at this period. Its total length at the end of the month, measured from vertex to heels, is 35-36 cm. (14-$14\frac{2}{5}$ in.), and its weight is about one and a half kilogrammes ($3\frac{1}{3}$ lbs.).

Eighth month.—The skin is completely covered with sebaceous deposit which is thickest on the head and in the axillæ and groins, and its colour changes to a bright flesh tint. The umbilicus is farther from the pubis, but it is not yet at the centre of the body. The total length of the fœtus, from vertex to heels, is 40 cm. (16 in.), and its weight varies from 2 to $2\frac{1}{2}$ kilogrammes ($4\frac{1}{2}$-$5\frac{1}{2}$ lbs.).

Ninth month. — The hair begins to disappear from the body, but it remains long and abundant on the head. The skin becomes paler, the plumpness increases, and the umbilicus reaches the centre of the body. At the end of the ninth month, when the fœtus is born, it measures about 50 cm. from vertex to heels (20 in.), and it weighs from 3-$3\frac{1}{2}$ kilogrammes ($6\frac{6}{10}$-$7\frac{7}{10}$ lbs.).

The age of a fœtus may be estimated approximately by Hasse's rule, viz. Up to the fifth month the length in centimeters, the lower limbs being included, equals the square of the age in months, and after the fifth month the length in centimeters equals the age multiplied by five.

OSTEOLOGY.

THE SKELETON.

By Arthur Thomson.

The term **skeleton** (from the Greek, σκελετός, dried) is applied to the parts which remain after the softer tissues of the body have been disintegrated or removed, and includes not only the bones, but also the cartilages and ligaments which bind them together. In the restricted sense of the word the skeleton denotes the osseous framework of the body. It is in this sense that it is generally employed in human anatomy.

The skeleton serves to support the softer structures which are grouped around it, and also affords protection to many of the delicate organs which are lodged within its cavities. By the articulation of its several parts, its segments are converted into levers which constitute the passive portion of the locomotory system. Recent research has also proved that certain cells found in bone-marrow are intimately associated with the development and production of some of the corpuscles of the blood.

Bone may be regarded as white fibrous tissue which, having become calcified, has undergone subsequent changes, so as to be converted into true osseous tissue. Most probably all bone is of membranous origin, but it may pass through a stage in which cartilage plays an important part in its development. In many instances the cartilage persists, and is not converted into bone, as in the case of the articular cartilage which clothes the joint surfaces, the nasal septum, the cartilages of the nose, and the cartilages of the ribs. A persistence of the membranous condition is met with in man in the case of the tentorium cerebelli, which in some groups of animals (Carnivora) is converted into a bony partition.

Skeletal structures may be derived from each of the three layers of the trilaminar blastoderm. The **exo-skeleton** includes structures of ectodermal, and some of mesodermal origin in the shape of hair, nails, feathers, teeth, scales, armour-plates, etc., whilst the **endo-skeleton**, with which we are more particularly concerned, is largely derived from the mesoblastic tissue, but also includes the notochord, an entodermal structure which forms the primitive endo-skeleton, around which the axial skeleton is subsequently developed in the Vertebrata. The endo-skeleton is divisible into an axial portion, appertaining to the trunk and head, and an appendicular part associated with the limbs. It also includes the **splanchnic skeleton**, which comprises certain bones developed in the substance of some of the viscera, such as the os cordis and os penis of certain mammals. In man, perhaps, the cartilaginous framework of the trachea and bronchi may be referred to this system.

The number of the bones of the skeleton of man varies according to age. Owing to a process of fusion taking place during growth, the number in the adult is less than the number in the child. The following table does not include the sesamoid bones which are frequently developed in tendons, the most constant ossicles of this description being those in relation to the metacarpo-phalangeal joint of the thumb, and the metatarso-phalangeal joint of the great toe.

The table represents the number of bones distinct and separable during adult life:—

		Single Bones.	Pairs.	Total.
Axial skeleton	The vertebral column	26	...	26
	The skull	6	8	22
	The sternum	1	...	1
	The ribs	...	12	24
	The hyoid bone	1	...	1
Appendicular skeleton	The upper limbs	...	32	64
	The lower limbs	...	31	62
The ossicles of the ear		...	3	6
		34	86	206

Bones are often classified according to their shape. Thus **long bones**, that is to say, bones of elongated cylindrical form, are more or less characteristic of the limbs. **Broad** or **flat bones** are plate-like, and serve as protective coverings to the structures they overlie; the bones of the cranial vault display this particular form. Other bones, such as the carpus and tarsus, are termed **short bones**; whilst the bones of the cranial base, the face, and the vertebræ, are frequently referred to as **irregular bones.**

Various descriptive terms are applied to the prominences commonly met with on a bone, such as *tuberosity, eminence, protuberance, process, tubercle, spine, ridge, crest,* and *line.* These may be articular in their nature, or may serve as points or lines of muscular and ligamentous attachment. The surface of the bone may be excavated into *pits, depressions, fossæ, cavities, furrows, grooves,* and *notches.* These may be articular or non-articular, the latter serving for the reception of organs, tendons, ligaments, vessels, and nerves. In some instances the substance of the bone is hollowed out to form an *air space, sinus,* or *antrum.* Bones are traversed by *foramina* and *canals*; these may be for the entrance and exit of nutrient vessels, or for the transmission of vessels and nerves from one region to another. A *cleft, hiatus,* or *fissure* serves the same purpose. Channels of this kind are usually placed in the line of a suture, or correspond to the line of fusion of the primitive portions of the bone which they pierce.

Composition of Bone.—Bone is composed of a combination of organic and inorganic substances in about the proportion of one to two.

Organic matter (Fat Collagen)		31·04
Mineral matter—		
Calcic phosphate	58·23	
Calcic carbonate	7·32	
Calcic fluoride	1·41	68·97
Magnesic phosphate	1·32	
Sodic chloride	·69	
		100·00

The animal matter may be removed by boiling or charring. According to the completeness with which the fibrous elements have been withdrawn, so the brittleness of the bone increases. When subjected to high temperatures the earthy matter alone remains. By soaking a bone in acid the salts may be dissolved out, leaving only the organic part. The shape of the bone is still retained, though it has now become soft, and can be bent about in any direction.

Bone may be examined either in the fresh or dry condition. In the former state it retains all its organic parts, which include the fibrous tissue in and around it, the blood-vessels and their contents, together with the cellular elements found within the substance of the bone itself, and the marrow which occupies the lacunar spaces and marrow cavity. In the dried or macerated bone most of these have disappeared, though a considerable portion of the organic matter still remains, even in bones of great antiquity and in a more or less fossil condition. Considering its nature and the amount of material employed, bone possesses a remark-

able strength, equal to nearly twice that of oak, whilst it is capable of resisting a greater crushing strain; it is stated that a cubic inch of bone will support a weight of over two tons. Its elasticity is remarkable, and is of the greatest service in enabling it to withstand the shocks to which it is so frequently subjected. In regions where wood is scarce the natives use the ribs of large mammals as a substitute in the construction of their bows. Its hardness and density vary in different parts of the skeleton, and its permanency and durability exceed that of any other tissue of the body, except the enamel and dentine of the teeth. The osseous remains of a race over eighty centuries old is now being excavated in Egypt.

Structure of Bone.—The structure of the bone varies with the form of the bone examined. If a long bone be studied in section, the **shaft** or **diaphysis** is seen to be hollow, displaying a cavity of elongated shape, which contains the soft cellular marrow. Around this, the bone is deposited in spicules so as to form a loose osseous meshwork, which becomes denser as it reaches the circumference, and gradually merges with the compact layer which forms the outer investing envelope. The extremities of the bone, usually developed from separate or secondary centres called **epiphyses**, are composed of cancellous tissue, usually finer in the grain and not, as a rule, displaying any medullary cavity. Here the confining shell of bone is thin, and displays none of the stoutness which is so characteristic of the outer layers in the shaft. In the recent condition, the extremities are cartilage-covered where they enter into the formation of joints. In flat bones the osseous tissue is disposed in two compact layers, with a layer of softer cancellous bone, here called the **diploe**, sandwiched in between. There is no medullary cavity, although in certain regions the substance of the diploe may be absorbed, thus forming **air-spaces** or **air-sinuses.**

True bone differs from calcified cartilage or membrane in that it not merely consists of the deposition of earthy salts within its matrix, but displays a definite arrangement of its organic and inorganic parts. Dense bone merely differs from loose or cancellous bone in the compactness of its tissue, the characteristic feature of which is the arrangement of the osseous lamellæ to form what are called **Haversian systems.** These consist of a central or **Haversian canal** which contains the vessels of the bone. Around this the **osseous lamellæ** are arranged concentrically, separated here and there by interspaces called **lacunæ,** in which the bone corpuscles are lodged. Passing from these lacunæ are many fine channels called **canaliculi.** These are disposed radially to the Haversian canal, and pass through the osseous lamellæ. They are occupied by the slender processes of the bone corpuscles. Each Haversian system consists of from three to ten concentric rings of osseous lamellæ.

In addition to the lamellæ of the Haversian systems there are others which are termed the **interstitial lamellæ**; these occupy the intervals between adjoining Haversian systems, and consist of Haversian systems which have undergone a process of partial absorption. Towards the surface of the bone, and subjacent to the periosteal membrane which surrounds the shaft, there are lamellæ arranged circumferentially; these are sometimes referred to as the outer **fundamental lamellæ.** The **periosteal membrane** which surrounds the bone, and which plays so important a part in its development, sends in processes through the various Haversian systems, which carry with them vessels and cells, thus forming an organic meshwork around which the earthy salts are deposited.

The interior of the bone, viz. the **marrow cavity**, and the interspaces within the cancellous tissue, as well as some of the larger Haversian canals, are occupied by the **marrow** or **medulla** of the bone. This varies considerably in its composition in different bones. In the medullary cavity of the shafts of the long bones it consists mainly of fat cells, together with a few marrow cells proper, supported by a kind of retiform tissue, and is known as the **yellow marrow.** In other situations, viz. in the diploe of the cranial bones, in the cancellated tissue of the epiphyses of the long bones, the vertebræ, the sternum, and the ribs, the marrow is more fluid in its consistence, contains less fat, but is characterised by the presence of marrow-cells proper, which resemble in some respects colourless blood corpuscles. In addition to these, however, there are smaller reddish coloured cells, akin to the nucleated red

corpuscles of the blood of the embryo. It is these cells (erythroblasts) which are concerned in the formation of the coloured corpuscles of the blood. Marrow which displays these characteristic appearances is distinguished from the yellow variety already described by being called the **red marrow.** In the diploe of the cranial bones of aged individuals the marrow, which has undergone degenerative changes, is sometimes referred to as the **gelatinous marrow.**

Apart from the adaptation of form rendered necessary by the use to which the bone is put, external influences are seen to react upon the intimate structure of the bone itself. Thus, if sections of different bones be made, the structural arrangement of their cancellous and dense tissue is seen to vary. In long bones the walls of the shaft are thick and strong, more particularly towards the concave side if the shaft happens to be bent. The marrow cavity—largest towards the centre—gradually tapers towards the extremities, being encroached upon by the surrounding cancellous tissue, which is disposed in lines converging towards the extremities like the sides of a vaulted arch, thereby forming platforms on which the epiphyses are supported. The surfaces of these platforms are not smooth, but so arranged as best to withstand the strain to which the epiphyses are habitually subjected. Such provision is necessary in order to obviate the tendency to separation, which might otherwise occur prior to the complete osseous union of the diaphysis with the epiphysis. In the epiphysis itself the arrangement of the fibres of the cancellous tissue is determined by the disposition of the articular surfaces. The osseous lamellæ, as a rule, are disposed at right angles to the planes of the articular facets, whilst they are bound together by other lamellæ arranged conformably with these articular planes. The former correspond to the direction of greatest pressure, whilst the latter agree with the lines of greatest tension. In cases where there is an outstanding process projecting from the shaft, as, for example, the head and neck of the femur, a section of the bone displays a bracket-like arrangement of the osseous fibres of the cancellous tissue, which assists materially in strengthening the bone.

Ossification and Growth of Bones.—For an account of the earlier development of the skeleton the reader is referred to the section on Embryology. Concerning the subsequent changes which take place, these are dependent on the conversion of the scleratogenous tissue into membrane and cartilage. A characteristic of this tissue is that it contains elements which become formed into bone-producing cells, called **osteoblasts.** These are met with in the connective tissue from which the membrane bones are formed, whilst they also appear in the deeper layers of the investing tissue of the cartilage (perichondrium), and so lead to its conversion into the bone-producing layer or periosteum. All true bone, therefore, may probably be regarded as of membranous origin, though its appearance is preceded in some instances by the deposition of cartilage; in this case calcification of the cartilage is an essential stage in the process of bone formation, but the ultimate conversion into true bone, with characteristic Haversian systems, leads to the absorption and disappearance of this primitive calcified cartilage.

Membrane bones are such as have developed from fibrous tissue without having passed through a cartilaginous stage. Of this nature are the bones of the cranial vault and the majority of the bones of the face, viz. the superior maxillæ, malars, nasals, lachrymals, and palate bones, as well as the vomer. The internal pterygoid plate is also of membranous origin.

Cartilage bones are those which are preformed in cartilage, and include most of the bones of the skeleton. Their growth is often described as endochondral and ectochondral, the former term implying the deposition of membrane bone in the centre of the cartilage, while the latter signifies a deposit of membrane bone on the surface of the cartilage, the osteogenetic layer on the surface of the cartilage being called the perichondrium till once bone has been formed, when it is called the periosteum.

In the course of the development of a bone from membrane, as, for example, the parietal bone, the fibrous tissue corresponding to the position of the primary centre becomes osteogenetic, because here appear the bone-forming cells (osteoblasts), which rapidly surround themselves with a bony deposit more or less spicular in

arrangement. As growth goes on these osteoblasts become embedded in the ossifying matrix, and remain as the corpuscles of the future bone, the spaces in which they are lodged corresponding to the lacunæ and canaliculi of the fully developed osseous tissue. From the primary centre ossification spreads eccentrically towards the margins of the bone, where ultimately the sutures are formed. Here the growth rendered necessary by the expansion of the cranium takes place through the agency of an intervening layer of vascular connective tissue rich in osteoblasts; but in course of time the activity of this is reduced until only a thin layer of intermediate tissue persists along the line of the suture; this may eventually become absorbed, leading to the obliteration of the suture by the osseous union of the contiguous bones. Whilst the expansion of the bone in all directions is thus provided for, its increase in thickness is determined by the activity of the underlying and overlying strata. These form the periosteum, and furnish the lamellæ which constitute the inner and outer compact osseous layers.

In a cartilage bone changes of a similar nature occur. The cartilage, which may be regarded histologically as white fibrous tissue + chondro-sulphuric acid and a certain amount of lime salts, undergoes the following changes:—**First**, the cartilage cells being arranged in rows, become enlarged; **secondly**, the matrix between the cartilage cells becomes calcified by the deposition of an additional amount of lime salts; **thirdly**, the rows of cells become confluent; and, **fourthly**, into the spaces so formed extend the blood-vessels derived from the vascular layer of the periosteum. Accompanying these vessels are osteoblasts and osteoclasts, the former building up true bone at the expense of the calcified cartilage, the latter causing an absorption of the newly-formed bone, and leading to its conversion into a marrow cavity, so that in due course all the cartilage or its products disappear. At the same time that this is taking place within the cartilage, the perichondrium is undergoing conversion into the periosteum, an investing membrane, the deeper stratum of which, highly vascular, furnishes a layer of osteoblast cells which serve to develop the circumferential lamellæ of the bone. It is by the accrescence of these layers externally, and their absorption internally through the action of the osteoclast cells, that growth takes place transversely. A transverse section of the shaft of a long bone shows this very clearly. Centrally there is the marrow cavity, formed primarily by the absorption of the calcified cartilage; around this the cancellous tissue produced by the partial erosion of the primary periosteal bone is disposed, whilst externally there is the dense envelope made up of the more recent periosteal growth.

Such a description, whilst explaining the growth of bone circumferentially, fails to account for its growth in length; hence the necessity in long bones for some arrangement whereby ossification may take place at one or both extremities of the shaft. This zone of growth is situated where the ossified shaft becomes continuous with the cartilaginous epiphysis. In addition, within these epiphysial cartilages calcification of the cartilage takes place centrally, just as in the diaphysis. The two parts of the bone, viz. the diaphysis and epiphysis, are thus separated by a layer of cartilage, as yet uncalcified, but extremely active in growth owing to the invasion of vessels and cells from a vascular zone which surrounds the epiphysis. The nucleus of the epiphysis becomes converted into true bone, which grows eccentrically. This arrangement provides for the growth of the shaft towards the epiphysis, and the growth of the epiphysis towards the shaft; so that as long as the active intervening layer of cartilage persists, extension of growth in a longitudinal direction is possible. Subsequently, however, at variable periods the intervening layer of cartilage becomes calcified, and true bony growth occurs within it, thus leading to complete osseous union between the shaft and epiphysis. When this has taken place all further growth in a longitudinal direction ceases. In cases where the epiphysis enters into the formation of a joint, the cartilage over the articular area persists and undergoes neither calcification nor ossification. In long bones the ossific nucleus for the shaft or diaphysis is the first to appear, and is hence often called the primary centre of ossification. The centres for the epiphyses appear subsequently at variable periods, and are referred to as the secondary centres of ossification.

From what has been said it will be gathered that the vascular supply of the bone is derived from the vessels of the periosteum. These consist of fine arteries

which enter the surface of the shaft and epiphysis; but in addition there is a larger trunk which enters the diaphysis and reaches the medullary cavity. This is called the **nutrient artery** of the bone. The direction taken by this vessel varies in different bones. In the upper limb the artery runs downwards in the case of the humerus and upwards in the radius and ulna; in the lower limb the nutrient vessel of the femur is directed towards the upper extremity of the shaft, whilst in the tibia and fibula it follows a downward course. It is difficult to account for this difference in the arrangement of the vessels; but it has been pointed out that when all the joints are flexed, as in the position occupied by the fœtus in utero, the direction taken by the vessels is the same, and corresponds to a line passing from the head towards the tail-end of the embryo. Consequently, in the upper limb the vessels flow towards the elbow, whilst in the lower limb they pass from the knee.

The attention of anatomists has long been directed to the elucidation of the laws which regulate bone-growth. Our present knowledge of the subject may be briefly summarised in the following generalisations:—

1. In bones with a shaft and two epiphyses, the epiphysis towards which the nutrient artery is directed is the first to unite with the shaft.

2. In bones with a shaft and two epiphyses, as a rule the epiphysis which commences to ossify latest unites soonest with the shaft. (The fibula is a notable exception to this rule. See p. 239.)

3. In bones with a shaft and one epiphysis the nutrient artery is directed towards the end of the bone which has no epiphysis. (This arrangement holds good in the case of the clavicle, the metacarpus, metatarsus, and phalanges.)

4. When an epiphysis is ossified from more than one centre, coalescence takes place between the separate ossific nuclei before the epiphysis unites with the shaft.

Highly suggestive, too, are the following propositions—That ossification first commences in the epiphysis which ultimately acquires the largest relative proportion to the rest of the bone, and that the ossification of the epiphysis is also correlated with its functional importance. In cases of long bones with only one epiphysis, the epiphysis is placed at the end of the bone where there is most movement.

The **veins** which permeate the cancellous texture of the bone are large and thin-walled. They do not accompany the arteries, and, as a rule, in long bones they escape through large openings near the articular surface. In flat bones they occupy channels within the diploe, and drain into an adjacent sinus, or form communications with the superficial veins of the scalp.

The **lymphatics** are mainly periosteal, but enter the bone along with the vessels and become perivascular.

The **nerves** which accompany the arteries are probably destined for the supply of the coats of these vessels. Whether they end in the bony tissue or not is unknown.

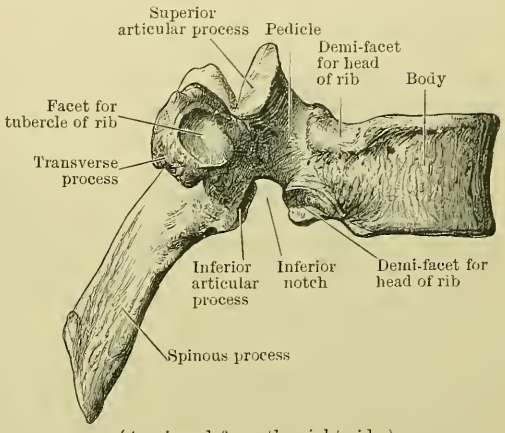
THE VERTEBRAL COLUMN.

The **vertebral column** (columna vertebralis) of man consists of thirty-three segments or **vertebræ**, placed one on the top of the other. In the adult, certain of these vertebræ have become fused together in the process of growth to form bones, the segmental arrangement of which is somewhat obscured, though even in their fully-developed condition sufficient evidence remains to demonstrate their compound nature. The vertebræ so blended are termed the **fixed** or **false vertebræ**, whilst those between which osseous union has not taken place are described as the **movable** or **true vertebræ**. This fusion of the vertebral segments is met with at either extremity of the vertebral column, more particularly below, where the column is modified to adapt it for union with the girdle of the lower limb, and also in the region of man's degenerated caudal appendage. But a partial union of the vertebral segments also takes place above, between the two highest vertebræ, in association with the mechanism necessary to provide for the movements of the head on the column.

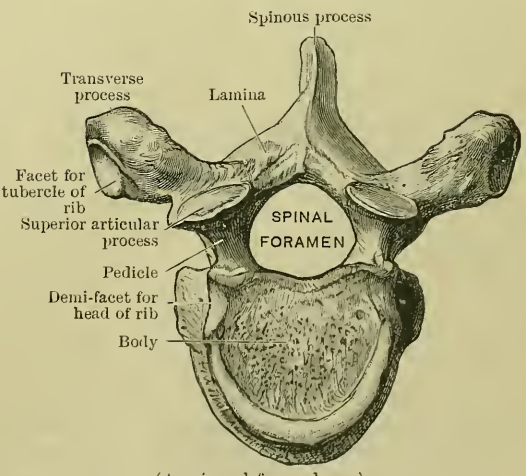
For descriptive purposes the vertebral column is subdivided according to the regions through which it passes. Thus the vertebræ are described as **cervical** (vertebræ cervicales), **dorsal** or **thoracic** (vertebræ thoracales), **lumbar** (vertebræ lumbales), **sacral** (vertebræ sacrales), and **coccygeal** (vertebræ caudales), according as they lie in the regions of the neck, back, loins, pelvis, and tail. The number of vertebræ met with in these regions is fairly constant, though, as will be hereafter pointed out, variations may occur in the number of the members of the different series. The vertebræ in man are thus apportioned—7 cervical, 12 dorsal, 5 lumbar, 5 sacral, and 4 or 5 coccygeal; the three former groups comprise the **true** or **movable** vertebræ, the two latter the **false** or **fixed** vertebræ. The **vertebral formula** may be thus expressed:—

Movable or **True Vertebræ.**			**Fixed** or **False Vertebræ.**		
Cervical.	Dorsal.	Lumbar.	Sacral.	Coccygeal.	
7	12	5	5	4	= 33.

The **vertebræ** of which the column is built up, though displaying great diversity of characters in the regions above enumerated, yet preserve certain features in common. All possess a solid part, **centrum** or **body** (corpus vertebræ); all have **articular processes** by which they articulate with their fellows; most have **muscular processes** developed in connexion with them; whilst the majority display a **vertebral** or **spinal foramen** (foramen vertebrale) formed by the union of a bony **arch** (arcus vertebræ) with the body. These common characters may best be studied by selecting for description an intermediate member of the series. For this purpose one of the middle or lower thoracic vertebræ may be chosen.



(As viewed from the right side.)



(As viewed from above.)

FIGS. 57, 58.—FIFTH THORACIC VERTEBRA.

A typical vertebra may be described as consisting of a **body** or **centrum** (corpus vertebræ) composed of a mass of spongy bone, more or less cylindrical in form. The size and shape of the body is liable to considerable variation according to the vertebra examined. The upper and lower surfaces of the body are very slightly concave from before backwards and from side to side, due to the thickening of the bone around its margins. In the recent condition these surfaces afford attachment for the intervertebral discs which are placed like pads between the bodies of the movable members of the series. The circumference of the body, formed as it is of more compact bone than the interior, is usually slightly concave from above downwards, though it becomes flat behind, where the body forms the anterior boundary of the spinal or vertebral foramen, at which point it is usually slightly concave from side to side. The vertical surfaces of the body are pierced here and there by foramina for the

passage of nutrient vessels, more particularly on the posterior surface, where a depression of considerable size receives the openings of the canals through which some of the veins which drain the body of the bone escape. Connected with the body posteriorly there is a bony **arch** (arcus vertebræ), which, by its union with the body, encloses a foramen of variable size, the **spinal** or **vertebral foramen** (foramen vertebrale). When the vertebræ are placed on the top of each other these foramina form with the uniting ligaments a continuous canal—**spinal** or **neural canal**—in which the spinal cord with its coverings is lodged. The **arch**, which is formed by the union of the **pedicles** and **laminæ**, besides enclosing the spinal foramen, also supports a certain number of processes; of these, some are outstanding, and may be regarded as a series of levers to which muscles are attached, whilst others are **articular** and assist in uniting the different vertebræ together by means of a series of movable joints. The **pedicles** are the bars of bone which pass from the back of the body of the vertebræ on either side to the points where the articular processes are united to the arch. The pedicles are compressed laterally, and have rounded superior and inferior borders. Since the vertical breadth of the pedicles is not as great as the thickness of the body to which they are attached, it follows that when the vertebræ are placed one above the other a series of intervals is left between the pedicles of the different vertebræ. These spaces, enclosed in front by the bodies of the vertebræ and their intervertebral discs, and behind by the coaptation of the articular processes, form a series of holes communicating with the neural or spinal canal; these are called the **intervertebral foramina** (foramina intervertebralia), and allow of the transmission of spinal nerves and vessels. As each intervertebral foramen is bounded above and below by a pedicle, the grooved surfaces in correspondence with the upper and lower borders of the pedicles are called the **upper** and **lower intervertebral grooves** or **notches** (incisura vertebralis superior et inferior). Posteriorly, the two pedicles are united by two somewhat flattened plates of bone—the **laminæ**, which converge towards the middle line, and become fused with the root of the projecting **spinous process** (processus spinosus). The breadth of the laminæ and their sloping arrangement are such, that when the vertebræ are articulated together they leave little space between them, thus enclosing fairly completely the neural canal, of which they form the posterior wall. The edges and inner surfaces of the laminæ are rough for the attachment of the ligaments which bind them together.

The **muscular processes** are three in number, viz. two **transverse processes**—one on either side—and one central or median, the **spinous process.** The former (processus transversus) project outwards on either side from the arch at the point where the pedicle joins the lamina. The latter (processus spinosus) extends backwards in the middle line from the point of fusion of the laminæ. The spinous processes display much variety of length and form.

The **articular processes** (zygapophyses), four in number, are arranged in pairs—one superior, the other inferior; the former are placed on the upper surface of the arch where the pedicles and laminæ join, the latter below the arch in correspondence with the superior. Whilst differing much in the direction of their articular surfaces, the upper have generally a backward tendency, whilst the lower incline forwards.

THE TRUE OR MOVABLE VERTEBRÆ.

The Cervical Vertebræ.

The **cervical vertebræ** (vertebræ cervicales), seven in number, can be readily distinguished from all the other vertebræ by the fact that their transverse processes are pierced by a foramen. The two highest, and the lowest, require special description; the remaining four conform to a common type.

Their **bodies**, the smallest of all the true vertebræ, are oblong in shape, the transverse diameter being much longer than the antero-posterior width. The upper surface, which slopes from behind forwards and downwards, is concave from side to side, owing to the marked projection of its lateral margins. Its anterior lip is rounded off, whilst its posterior edge is sharply defined.

The inferior surface, which is more or less saddle-shaped, is directed downwards and backwards. It is convex from side to side, and concave from before backwards, with a slight rounding off of the projecting anterior lip. The vertical diameter of the body is small in proportion to its width. The anterior surface is flat in the middle line, but furrowed laterally. The posterior surface, which is rough and pierced by many small foramina, is flat from side to side and above downwards; it forms in its entire extent the anterior wall of the spinal foramen. The lateral aspects of the body, particularly in their upper parts, are fused with the costal parts of the transverse processes, and form the inner wall of the vertebrarterial foramen (foramen transversarium).

The **pedicles** which spring from the posterior half of the lateral aspects of the body, about equidistant from their upper and lower margins, are directed horizontally backwards and outwards. The **superior** and **inferior notches** are nearly equal in depth.

The **laminæ** are long, and about as wide as the body of the bone is thick.

The **spinal foramen** is larger than in the thoracic and lumbar regions; its shape is triangular, or more nearly semilunar.

The **transverse processes**, so called, are pierced by the vertebrarterial foramen

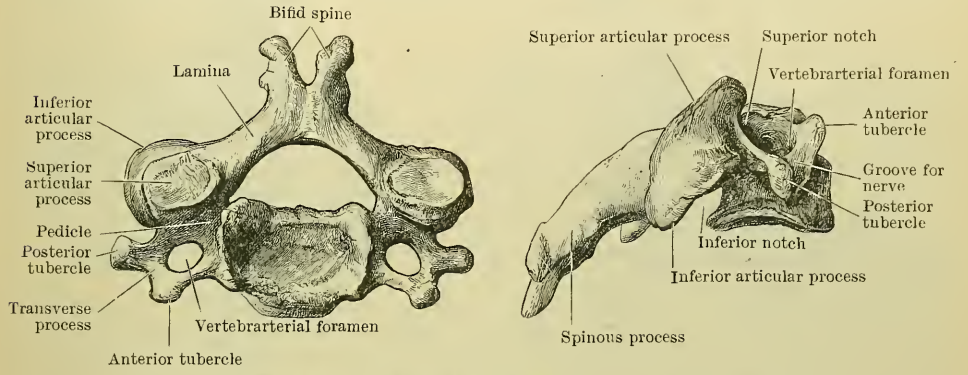


Fig. 59.—Fourth Cervical Vertebra from Above and from the Right Side.

(foramen transversarium). They consist of two parts—the part behind the foramen, which springs from the neural arch and is the true transverse process, and the part in front, which is homologous with the ribs in the thoracic portion of the column. These two processes, united externally by a bridge of bone, which thus converts the interval between them into a foramen, terminate in two tubercles, known respectively as the **anterior** and **posterior tubercles**. The general direction of these processes is outwards, slightly forwards, and a little downwards, the anterior tubercles lying internal to the posterior. The two tubercles are separated above by a groove directed outwards, downwards, and forwards; along this the spinal nerve trunk passes. The **vertebrarterial foramen** (foramen transversarium), often subdivided by a spicule of bone, is traversed by the vertebral artery and vein in the upper six vertebræ. The **spinous processes**, which are directed downwards, are short, compressed vertically, and bifid. The **articular processes** are supported on cylindrical masses of bone fused with the arch where the pedicles and laminæ join. These cylinders are sliced away obliquely above and below, so that the superior articular facets, more or less circular in form, are directed upwards and backwards, whilst the corresponding inferior surfaces are turned downwards and forwards.

Variations.—Szawlowski records the presence of an independent rib element in the transverse process of the fourth cervical vertebra. (*Anat. Anz. Jena*, vol. xx. p. 306.)

First Cervical Vertebra or **Atlas.**—This bone may be readily recognised by the absence of the body and spinous process. It consists of two **lateral masses**, which support the articular and transverse processes. The lateral masses are themselves united by two curved bars of bone, the **anterior** and **posterior arches**, of which the former is the stouter and shorter. Each **lateral mass** is irregularly six-sided, and so placed that it lies closer to its fellow of the opposite side in front than

behind. Its upper surface is excavated to form an elongated **oval facet**, concave from before backwards, and inclined obliquely inwards; not infrequently this articular surface displays indications of division into two parts. These facets are for the reception of the condyles of the occipital bone.

The **inferior articular facets** are placed on the under surfaces of the lateral masses. Of circular form, they display a slight side-to-side concavity, though flat in the antero-posterior direction. Their disposition is such that their surfaces incline downwards and slightly inwards. They rest on the superior articular processes of the second cervical vertebra. Springing from the anterior and inner aspects of the lateral masses, and uniting them in front, is a curved bar of bone, the **anterior arch** (arcus anterior); compressed on either side, this is thickened centrally so as to form on its anterior aspect the rounded **anterior tubercle** (tuberculum anterius). In correspondence with this on the posterior surface of this arch is a **circular facet** (fovea dentis) for articulation with the odontoid process of the second cervical vertebra (axis).

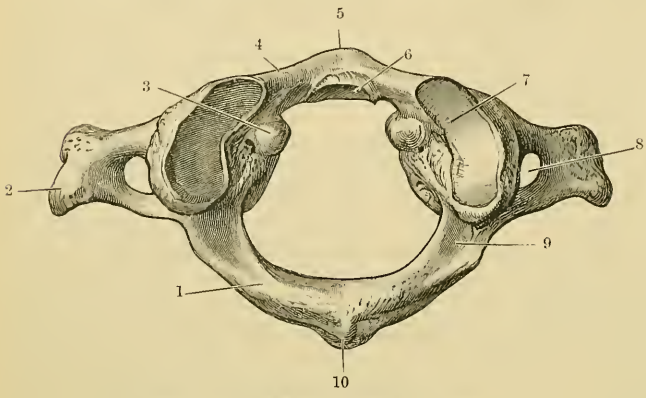


Fig. 60.—The Atlas from Above.

1. Posterior arch.
2. Transverse process.
3. Tubercle for transverse ligament.
4. Anterior arch.
5. Anterior tubercle.
6. Surface for articulation with odontoid process.
7. Superior articular process.
8. Foramen for vertebral artery.
9. Groove for vertebral artery.
10. Posterior tubercle.

The inner surface of the lateral mass is rough and irregular, displaying a little **tubercle** for the attachment of the tranverse ligament which passes across the space included between the two lateral masses and the anterior arch, thus holding the odontoid process of the axis in position. Behind each tubercle there is usually a deep pit, opening into the bottom of which are the canals for the nutrient vessels.

External to the lateral mass, and principally from its upper half, the transverse process arises by two roots which include between them the vertebrarterial foramen. The **transverse process** is long, obliquely compressed, and down-turned; the anterior and posterior tubercles are no longer distinguishable, as they have fused to form one mass.

The **posterior arch** arises in part from the posterior surface of the lateral mass, and in part from the posterior root of the transverse process. Compressed from above downwards anteriorly, where it bounds a groove which curves around the posterior aspect of the superior articular process, which groove is also continuous externally with the vertebrarterial foramen, the posterior arch becomes thicker mesially, at which point it displays posteriorly a rough irregular projection—the **posterior tubercle** (tuberculum posterius), the feeble representative of the spinous process. A prominent little tubercle, arising from the posterior extremity of the superior articular process, overhangs the groove above mentioned, and not infrequently becomes developed so as to form a bridge of bone across it, converting the groove into a canal through which the vertebral artery and the first cervical or suboccipital nerve pass—a condition normally met with in many animals. It is noteworthy that the grooves traversed by the two highest spinal nerves lie behind the articular processes, in place of in front, as in other parts of the column.

The **ring** formed by the lateral masses and the anterior and posterior arches is of irregular outline. The anterior part, cut off from the rest by the transverse ligament, serves for the lodgment of the odontoid process of the axis; the larger part behind corresponds to the upper part of the neural or spinal canal.

Variations.—The vertebrarterial foramen is often deficient in front. Imperfect ossification occasionally leads to the anterior and posterior arches being incomplete. The superior articular

surfaces are occasionally partially or completely divided into anterior and posterior portions. In some instances the extremity of the transverse process has two tubercles. The transverse process may, in rare cases, articulate with a projecting process (paroccipital) from the under surface of the jugular process of the occipital bone (see p. 113). An upward extension from the median part of the anterior arch, due probably to an ossification of the anterior occipito-atlantal ligament, may articulate with the anterior surface of the summit of the odontoid process of the axis. Allen has noticed the articulation of the superior border of the posterior arch with the posterior border of the foramen magnum. Cases of partial or complete fusion of the atlas with the occipital bone are not uncommon (see p. 113).

Second Cervical Vertebra, Axis, or **Epistropheus.**—This is characterised by the presence of the tooth-like **odontoid process** (dens) which projects upwards from the superior surface of the body. Slightly constricted where it joins the body, the odontoid process tapers to a blunt point superiorly, on the sides of which there are surfaces for the attachment of the odontoid or check ligaments. When the atlas and axis are articulated together this process lies behind the anterior arch of the atlas, and displays on its anterior surface an oval or circular facet which articulates with that on the posterior surface of the anterior arch of the atlas. On the

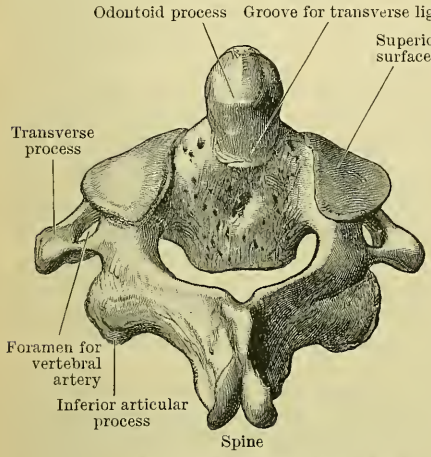


Fig. 61.—Axis from Behind and Above.

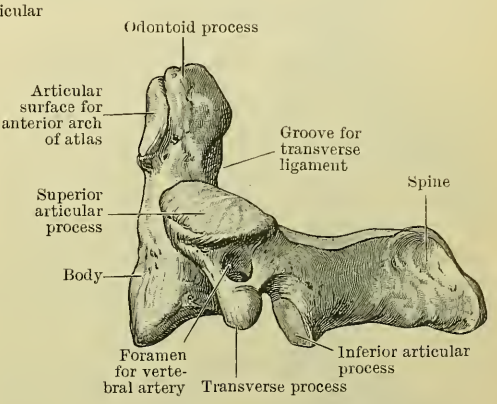


Fig. 62.—Axis from the Left Side.

posterior aspect of the neck of the odontoid process there is a shallow groove which receives the transverse ligament which holds it in position.

The anterior surface of the **body** has a raised triangular surface, which ends superiorly in a ridge passing upwards to the neck of the odontoid process. The **pedicles** are concealed above by the superior articular processes; inferiorly, they are deeply grooved. The **laminæ**—prismatic on section—are thick and strong, ending in a stout, broad, and **bifid spinous process**, the under surface of which is deeply grooved, whilst its sides meet superiorly in a ridge. Placed over the pedicles and the anterior root of the transverse processes are the **superior articular surfaces.** These are more or less circular in shape, slightly convex from before backwards, flat from side to side, and have a direction upwards and a little outwards. They are channelled inferiorly by the vertebrarterial foramina which turn outwards beneath them. The grooves by which the second cervical nerves leave the neural canal cross the laminæ immediately behind the superior articular processes. The **inferior articular processes** agree in form and position with those of the remaining members of the series, and are placed behind the inferior intervertebral notches.

The **transverse process** is markedly down-turned, with a single pointed extremity.

Variations.—In some instances the summit of the odontoid process articulates with a prominent tubercle on the anterior border of the foramen magnum (third occipital condyle, see p. 113). Bennet (*Trans. Path. Soc. Dublin*, vol. vii.) records a case in which the odontoid process was double, due to the persistence of the primitive condition in which it is developed from two centres. Occasionally the odontoid process fails to be united with the body of the axis, forming an os odontoideum comparable to that met with in the crocodilia (Giacomini, Romiti, and

Turner). The vertebrarterial foramen is not infrequently incomplete, owing to the imperfect ossification of the posterior root of the transverse process.

The **seventh cervical vertebra**, or **vertebra prominens**, receives the latter name from the outstanding nature of its **spinous process**, which ends in a single broad tubercle. This forms a well-marked surface projection at the back of the root of the neck. The **transverse processes** are broad, being flattened from above downwards; they project considerably beyond those of the sixth. The maximum width between their extremities agrees with that between the transverse processes of the atlas, these two constituting the widest members of the cervical series. The **vertebrarterial foramen** is small. Not infrequently the costal element is separate from the true transverse process, thus constituting a **cervical rib**.

Variations.—The vertebrarterial foramen may be absent on one or other side.

Thoracic Vertebræ.

The **thoracic** or **dorsal vertebræ** (vertebræ thoracales), twelve in number, are distinguished by having facets on the sides of their bodies for the heads of the ribs, and in most instances also articular surfaces on their transverse processes for the tubercles of the ribs (Figs. 57 and 58, p. 75).

The **body** is described as characteristically heart-shaped, though in the upper and lower members of the series it undergoes transition to the typical forms of the cervical and lumbar vertebræ respectively. Its antero-posterior and transverse widths are nearly equal; the latter is greatest in line with the facets for the heads of the rib. The bodies are slightly thicker behind than in front, thus adapting themselves to the anterior concavity which the column displays in this region. The bodies of the second to the ninth thoracic vertebræ inclusive, each possess four **costal demi-facets**—a superior pair placed on the upper margin of the body, close to the junction of the pedicle with the centrum, and an inferior pair situated on the lower edge, close to and in front of the inferior intervertebral grooves.

When contiguous vertebræ are articulated, the upper pair of demi-facets of the lower vertebra coincide with the lower demi-facets of the higher vertebra, and, together with the intervening intervertebral disc, form an articular cup for the reception of the head of a rib. Of these facets on the body the upper pair are the primary articular surfaces for the head of the rib; the lower are only acquired secondarily. Moreover, these facets, though apparently placed on the body, are in reality developed on the sides of the pedicles behind the line of union of the pedicles with the centrum (neuro-central synchondrosis), as will be explained hereafter.

The **pedicles** are short and thick, and directed backwards and slightly upwards. The superior notch is faintly marked; the inferior notch is deep. The **laminæ** are broad, flat, and sloping, having sharp upper and lower margins. When the vertebræ are superposed the latter overlap the former so as to form an imbricated arrangement. The **spinal foramen** is smaller than in the cervical and lumbar regions, and nearly circular in shape.

The **spinous processes** vary in length and direction, being shorter and more horizontal in the upper and lower members of the series, longest and most oblique in direction towards the middle of this part of the column. Nearly all have a downward inclination, and are so arranged that they overlap one another. Triangular in section where they spring from the neural arch, they become laterally compressed towards their extremities, which are capped by more or less distinct tubercles. The **transverse processes** are directed backwards and outwards, and a little upwards. They gradually decrease in size and length from above downwards. Each has a somewhat expanded extremity, the anterior surface of which, in the case of the upper ten vertebræ, is hollowed out in the form of a circular facet for articulation with the tubercle of the rib which rests in the upper demi-facet of the vertebra to which the transverse process belongs. The **superior articular processes** are vertical and have their surfaces directed backwards, slightly upwards, and a little outwards; the **inferior**, correspondingly forwards, downwards, and inwards.

Certain of the thoracic vertebræ display characters by which they can readily

be recognised. These are the first, tenth, eleventh, and twelfth, and sometimes the ninth.

The **first thoracic vertebra** resembles the seventh cervical in the shape of its body, and the length and direction of its spine. There is an entire facet on either side of the body for the head of the first rib, and one demi-facet on each side at the lower border of its body, to complete the socket for the head of the second rib. Its **transverse processes** are long, and the superior intervertebral notch is better marked than in other members of the thoracic series. The superior articular surfaces are directed backwards and upwards, not outwards as in the lower members of the series.

The **ninth thoracic vertebra** occasionally has only the upper pair of demi-facets on its body; at other times it conforms to the usual type.

The **tenth thoracic vertebra** may have only one complete costal facet on each side for the X. rib, though sometimes the articular socket may be completed by the ninth dorsal vertebra. The facet on the transverse process is generally small, and sometimes absent.

The **eleventh thoracic vertebra** has a complete circular facet on the outer side of each pedicle for articulation with the XI. rib. Its transverse processes are short and stunted, and have no facets.

The **twelfth thoracic vertebra** has a single facet on the pedicle on each side for the XII. rib. Its transverse processes, which have no facets, are broken up into smaller tubercles, called respectively the external, superior, and inferior tubercles. These are homologous with the transverse mammillary and accessory processes of the lumbar vertebræ. Indications of these processes may also be met with in the tenth and eleventh thoracic vertebræ. The

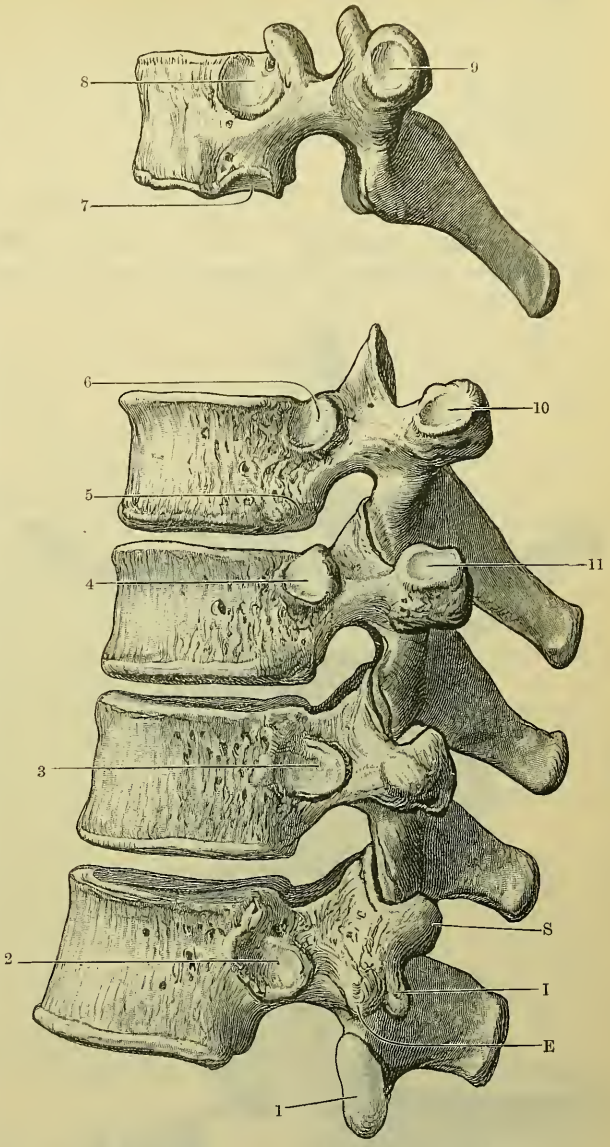


FIG. 63.—FIRST, NINTH, TENTH, ELEVENTH, AND TWELFTH THORACIC VERTEBRÆ FROM THE LEFT SIDE.

1. Inferior articular process with out-turned facet.
2. Single facet for head of XII. rib; no facet on transverse process.
3. Single facet for head of XI. rib; no facet on transverse process.
4. Single or demi-facet for head of X. rib.
5. Occasional demi-facet for head of X. rib.
6. Demi-facet for head of IX. rib.
7. Demi-facet for head of II. rib.
8. Single facet for head of I. rib.
9. Facet on transverse process for tuberosity of I. rib.
10. Facet on transverse process for tuberosity of IX. rib.
11. Facet on transverse process for tuberosity of X. rib, in this particular instance well marked.

S. Superior, I. Inferior, E. External — Tubercles corresponding to — Mammillary, Accessory, Transverse of lumbar.

twelfth thoracic vertebra may usually be distinguished from the eleventh by the arrangement of its inferior articular processes, which resemble those of the lumbar series in being out-turned; but the eleventh occasionally displays the same arrangement, in which case it is not always easy to distinguish between them.

Variations.—Barclay Smith (*Journ. Anat. and Physiol.* Lond. 1902, p. 372) records five cases in which the superior articular processes of the twelfth thoracic vertebra displayed thoracic and lumbar characteristics on the opposite sides.

Lumbar Vertebræ.

The **lumbar vertebræ** (vertebræ lumbales), five in number, are the largest of the movable vertebræ. They have no costal articular facets, nor are their transverse processes pierced by a foramen. In this way they can be readily distinguished from the members of the cervical and thoracic series.

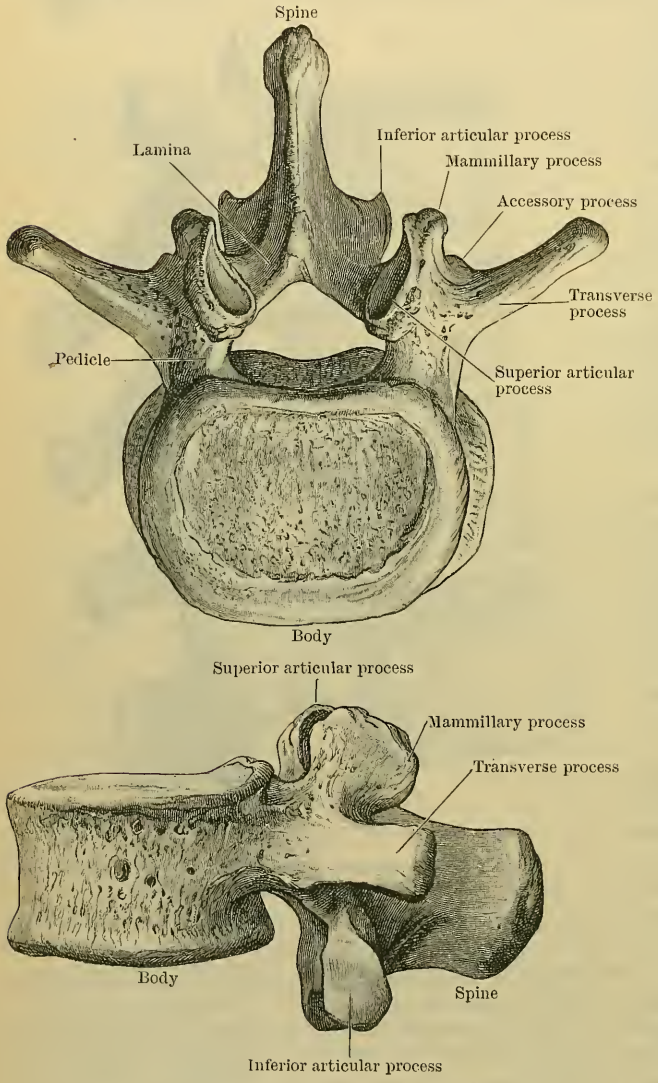


Fig. 64.—Third Lumbar Vertebra from Above, and from the Left Side.

The **body** is kidney-shaped in outline, and of large size. The transverse diameter is usually about a half greater than the antero-posterior width. The anterior thickness is slightly greater than the posterior, being thus adapted to the anterior convex curve of the column in this region. The **pedicles**, directed horizontally backwards, are short and stout; the superior notches are shallow, but deeper than in the thoracic region; the inferior grooves are deep. The **laminæ** are broad and nearly vertical, sloping but little. They support on their lower margins the inferior articular processes. The **spinal foramen** is large and triangular.

The **spinous processes**, spatula shaped, with a thickened posterior margin, project backwards and slightly downwards. The **transverse processes**, more slender than in the dorsal region, pass horizontally outwards, with a slight backward inclination. Arising from the junction of the pedicles with the laminæ in the higher members of the series, they tend to advance so as to become fused with the outer side of the pedicle and back of the body in the two lower lumbar vertebræ. In these latter vertebræ the superior intervertebral grooves are carried obliquely across the upper surfaces of the bases of the transverse processes. The transverse processes

lie in line with the external tubercles of the lower thoracic vertebræ, with which they are serially homologous, and are to be regarded as representing the costal element. Placed on their base posteriorly, and just external to and below the superior articular processes, are the small **accessory tubercles** (processus accessorii) which are in series with the inferior tubercles of the lower thoracic vertebræ. The **superior articular processes** are stout, oval, curved plates of bone, fused in front with the pedicles and laminæ, and having their concave articular surfaces vertical and in-turned. Externally, and on their posterior edge, the bone rises in the form of an elongated oval tubercle, the **mammillary process** (processus mammillaris); these are in correspondence with the superior tubercles of the lower thoracic transverse processes.

The **inferior articular processes** lie on either side of the root of the spinous process, supported on the inferior margin of the laminæ. Their articular surfaces, oval in outline, convex from side to side, and plane from above downwards, are out-turned. The inferior articular processes are much closer together than the superior; so that when the vertebræ are articulated the superior articular processes of the lower vertebra embrace the inferior articular processes of the higher vertebra.

The **fifth lumbar vertebra** is characterised by the size of its body, which is the largest of all the vertebræ. Further, the under surface of the body is cut away at the expense of its posterior part: hence the thickness of the centrum in front much exceeds that of the vertical diameter behind. The **transverse process** is pyramidal in form, and stouter than those of the other lumbar vertebræ. It arises by a broad base from the side of the back of the body, as well as from the pedicle, and is directed outwards and a little backwards and upwards. Its upper surface is slightly grooved by the superior intervertebral notch. A deep notch separates it posteriorly from the superior articular processes, which are less in-turned than in the other members of the series, their articular surfaces being directed more backwards than inwards, and displaying less concavity. The inferior articular processes are further apart than is the case with the other members of the series, they lie in line with the superior. The spinous process is shorter and narrower than the other lumbar spines, particularly so in the female.

Variations.—The mammillary and accessory processes are sometimes unduly developed. The neural arch of the fifth lumbar vertebra is occasionally interrupted on either side by a synchondrosis which runs between the upper and lower articular processes. In macerated specimens the two parts of the bone are thus separate and independent. The anterior includes the centrum, together with the pedicles, transverse and superior articular processes; the posterior comprises the inferior articular processes, the laminæ, and the spine.—(Turner, *Challenger Reports*, vol. xvi.) Szawlowski and Dwight record instances of the occurrence of a foramen in the transverse process of the V. lumbar vertebra (*Anat. Anz. Jena*, vol. xx.), and Ramsay Smith describes a case in which the right transverse process of the IV. lumbar vertebra of an Australian sprang from the side of the body in front of the pedicle, being unconnected either with the pedicle or articular process.

THE FALSE OR FIXED VERTEBRÆ.

The Sacrum.

The **sacrum** (os sacrum), of roughly triangular shape, is formed by the fusion normally, of five vertebræ. The **anterior surface** of the bone is slightly hollow from side to side and concave from above downwards, the curve being usually most pronounced opposite the third sacral segment. The central part corresponds to the bodies of the sacral vertebræ, the lines of fusion of which are indicated by a series of four parallel ridges which cross the central part of the bone at gradually diminishing intervals from above downwards; externally, these ridges disappear on either side on the inner walls of the four **anterior sacral foramina** (foramina sacralia anteriora). The size of these holes decreases from above downwards. The upper and under border of each foramen is formed by a stout bar of bone, of which there are five on each side, corresponding in number with the vertebræ present. These unite externally so as to form the **lateral mass** (pars lateralis), and thus enclose the foramina to the outer side, though here the edge is not abrupt, but

sloped so as to pass gradually into the canal. The large anterior divisions of the sacral nerves pass through these foramina and occupy the shallow grooves. The bone is broadest across the first sacral vertebra, tends to narrow opposite the second, and again usually increases in width opposite the third. When this condition is well marked, the edge has a notched appearance (sacral notch) which assists in the interlocking of the sacro-iliac joint; this feature is common in the Simiidæ and some of the lower races of mankind (Paterson). The surface of bone between and external to the first, second, third, and fourth foramina affords attachment to the fibres of origin of the pyriformis which may in some instances extend on to the bodies of the II. and III. segments (Adolphi), whilst on the edge external to and below the fourth foramen the coccygeus is inserted.

The **posterior surface** is rough and irregular. Convex from above downwards it displays mesially a **crest** (crista sacralis media) whereon are seen four elongated

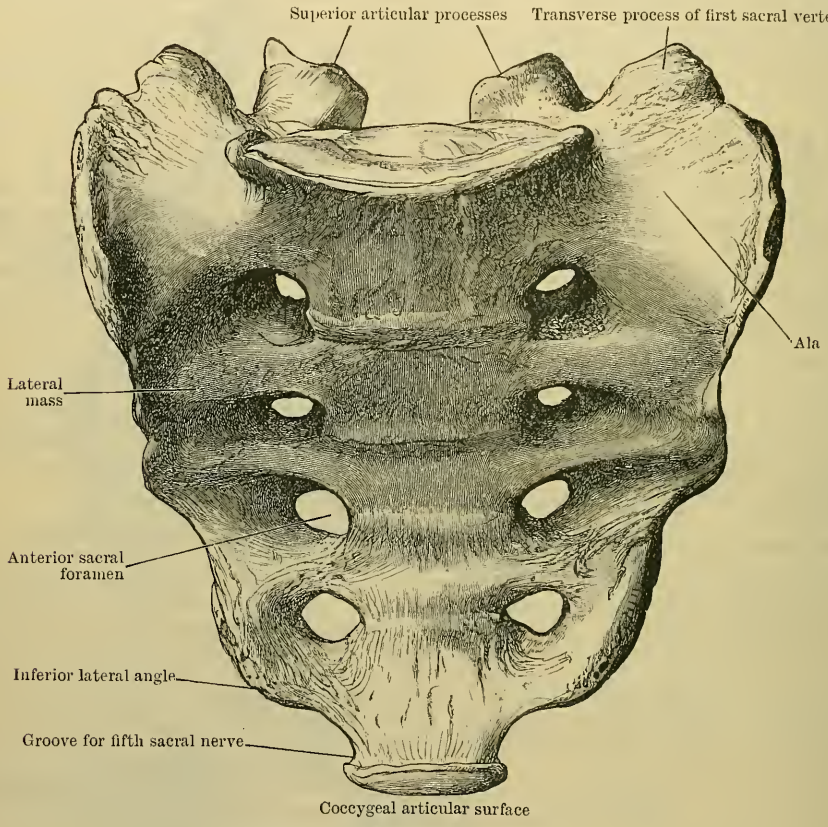


FIG. 65.—THE SACRUM (anterior view).

tubercles—the spines of the upper four sacral vertebræ. External to these the bone forms a groove—the **sacral groove**—the floor of which is made up of the confluent laminæ of the corresponding vertebræ. In line with the intervals between the spines, and wider apart above than below, another series of tubercles is to be seen. These are due to the fusion of the **articular processes** of the sacral vertebræ, and together they form faint irregular ridges on the bone (cristæ sacrales articulares). Normally, the spine of the lowest sacral segment is absent, and the laminæ do not coalesce mesially, thus leaving a gap in which the spinal canal is exposed (hiatus sacralis); whilst inferiorly the tubercles corresponding to the inferior articular processes of the last sacral vertebra form little down-projecting processes—the **sacral cornua** (cornua sacralia)—by means of which the sacrum is in part united to the coccyx. Just wide of the articular tubercles are the **posterior sacral foramina** (foramina sacralia posteriora), for the transmission of the posterior divisions of the sacral nerves. These are in correspondence with the anterior foramina, so that a

probe can be passed directly through both openings; but it is to be noted that the posterior are much smaller, and their margins much sharper, than is the case with the anterior. The surface of the lateral mass external to the posterior sacral foramina is rough and irregular, owing to the presence of four more or less elevated tubercles, which constitute the lateral ridges on either side of the bone (cristæ sacrales laterales), and which are serially homologous with the true transverse processes of the lumbar vertebræ.

The posterior surface of the bone furnishes an extensive surface for the origin of the erector spinæ muscles, whilst the edge of the bone external to the third and fourth foramen gives attachment to the gluteus maximus.

The **base** of the bone displays features more in accordance with a typical

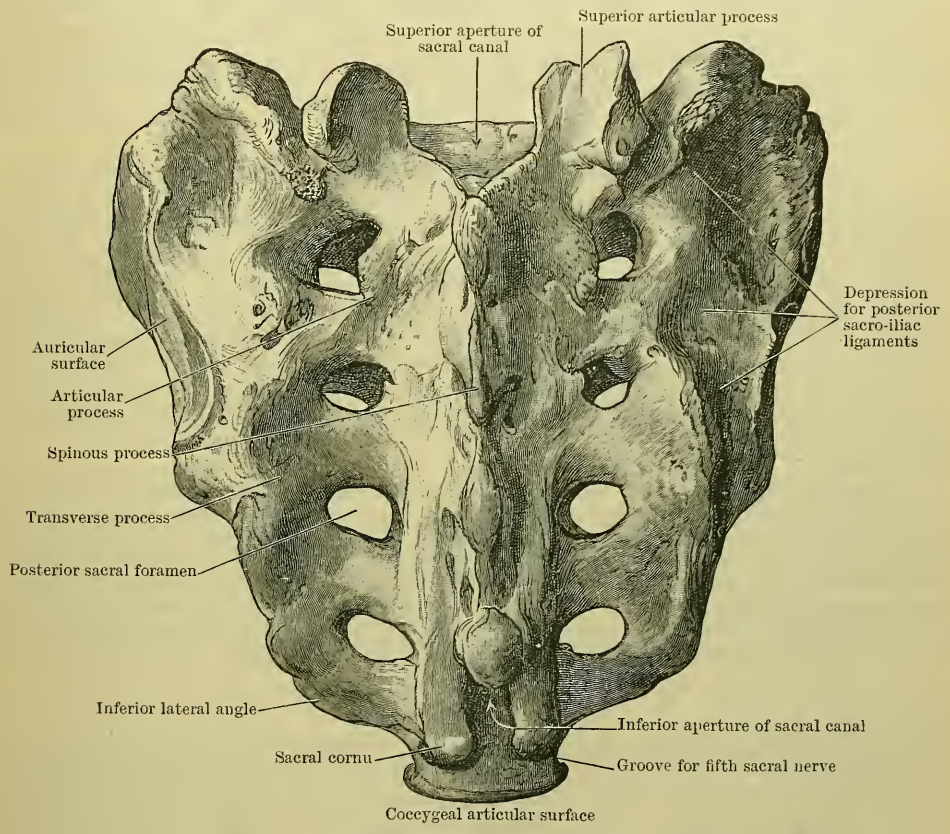


FIG. 66.—THE SACRUM (posterior view).

vertebra. Centrally, and in front, is placed the **body**, the upper surface of which articulates with the last lumbar vertebra through the medium of an intervertebral disc. The anterior margin is thin and projecting, overhanging the general concavity of the front of the bone, and forming what is called the **promontory** (promontorium). Behind the body, the spinal canal, of triangular form with slightly appressed sides, is seen, whilst posteriorly is the short spinous process forming the highest tubercle of the median crest. Spreading out from the sides, and partly from the back of the body on either side, is a fan-shaped mass of bone, the upper surface of which is slightly concave from side to side, and convex from above and behind downwards and forwards. This, the **ala** (ala sacralis), corresponds to the thick upper border of the **lateral mass**, and is formed, as will be explained hereafter, by elements which correspond to the pedicles and transverse processes of the sacral vertebræ, together with superadded structures—the sacral ribs. The external margin of the lateral mass, as seen from above, is sharp and outwardly convex, terminating behind in a prominent tubercle—the highest of the series of elevations seen on the posterior surface of the bone, which have been already described as serially homologous with

the true transverse processes of the lumbar vertebræ. Fused with the back of each lateral mass, and separated from it externally by a narrow but deep notch, is the **superior articular process**. This supports a vertical articular surface, which is of circular or oval form, and concave from side to side, having a general direction backwards and a little inwards.

The borders of the bone are thick above, where they articulate with the ilia, thin and tapering below, where they furnish attachments for the powerful sacro-sciatic ligaments. The **iliac articular surfaces** are described as auricular in shape (facies auriculares), and overlie the lateral masses formed by the first three sacral vertebræ, though this arrangement is liable to considerable variation. Behind the auricular surface the bone is rough and pitted by three distinct depressions for the attachment of the strong sacro-iliac ligaments. Inferiorly, the edge formed by the lateral masses of the fourth and fifth sacral vertebræ becomes gradually thinner, and at the **inferior lateral angle** changes its direction and sweeps inwards towards the body of the fifth sacral segment.

The **apex**, or lower end of the sacrum, is formed by the small oval body of the fifth sacral vertebra, which articulates with the coccyx.

The **sacral canal** follows the curve of the bone; more or less triangular in shape above, it becomes appressed and flattened below. Inferiorly, its posterior wall is deficient owing to the imperfect ossification of the laminæ of the fifth, and, it may be, of the fourth sacral segments. Passing obliquely outwards and downwards from this canal into the lateral masses on either side are the four pairs of intervertebral foramina, each of which is connected externally with a V-shaped canal which terminates in front and behind in the anterior and posterior sacral foramina. The hinder limb of the V is shorter and narrower than the anterior.

The female sacrum is proportionately broader than the male. Its curves are liable to great individual variation, though the absolute depth of the curve is less than in the male.

Variations.—The number of sacral segments may be increased to six or reduced to four (see p. 90). Transition forms are occasionally met with in which the first sacral segment displays on one side purely sacral characters, *i.e.* it articulates with the innominate bone, whilst on the opposite side it may present all the features of a lumbar vertebra. Through deficiency in the development of the laminæ, the neural canal may be exposed throughout its entire length, or to a greater extent than is normally the case. (Paterson, *Roy. Dublin Soc. Scientific Trans.* vol. v. Series II.) Szawlowski and Barclay Smith record the occurrence of a foramen in the lateral mass of the I. sacral vertebra (*Journ. of Anat. and Physiol.* Lond. vol. xxxvi. p. 372).

Coccyx.

The **coccyx** consists of four—sometimes five, less frequently three—rudimentary vertebræ, which tend to become fused. The **first piece** is larger than the others; it has an oval hollow facet on its upper surface, which articulates with the body of the last sacral segment. Posteriorly, two processes, **cornua coccygea**, which lie in series with the articular processes of the sacrum, extend upwards and unite with the sacral cornua, thus bridging over the notch for the exit of the fifth sacral nerve, and converting it into a foramen, the last of the intervertebral series. From the outer sides of the body project rudimentary **transverse processes** which may,

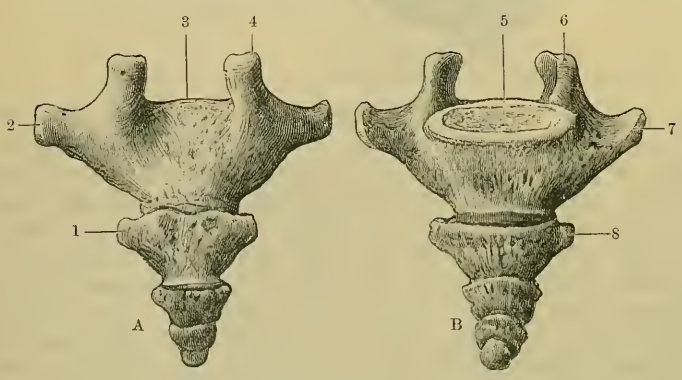


Fig. 67.—The Coccyx.

A. Posterior Surface. B. Anterior Surface.

1. Transverse process. 3. Sacrum. 5. Sacrum. 7. Transverse process.
2. Transverse process. 4. Cornu. 6. Cornu. 8. Transverse process.

or may not, unite with the sacrum close to the lower lateral angles; in the latter case the fifth anterior sacral foramina are enclosed. Inferiorly, the body of the bone articulates with the succeeding vertebra. The **second coccygeal vertebra** displays slight traces of a transverse process and the rudiments of pedicles. The following segments are mere rounded or oval-shaped nodules of bone.

Fusion between the lower elements occurs normally in middle life, whilst union between the first and second segments occurs somewhat later. It is not unusual, however, to find that the first coccygeal vertebra remains separate from the others. Though very variable, as a rule, fusion occurs more commonly in the male, and at an earlier age, than in the female. Szawlowski has recorded a case in which a curved process arose from the ventral surface of the first coccygeal segment. He regards this as possibly the homologue of a ventral arch (*Anat. Anz. Jena*, vol. xx. p. 320).

From the posterior surface of the coccyx the gluteus maximus arises. To its external borders are attached the coccygei and levatores ani muscles, and from its tip spring the fibres of the sphincter ani.

VERTEBRAL COLUMN AS A WHOLE.

When all the vertebræ are articulated together, the resulting column displays certain characteristic features. The division of the column into a true or movable part, comprising the members of the cervical, thoracic, and lumbar series, and a false or fixed portion, including the sacrum and coccyx, can now be readily recognised. The vertebræ are so disposed that the centra or bodies form an interrupted column of solid parts in front, which constitutes the axis of support for the head and trunk; whilst the neural arches behind constitute a canal for the lodgment and protection of the spinal cord and its membranes. In the movable part of the column both the anterior supporting axis and the neural canal are liable to changes in their disposition owing to the movements of the head and trunk. Like the bodies and neural arches, the spinous and transverse processes are also superposed, and fall in line, forming three series of interrupted ridges—one (the spinous) placed centrally and behind, the others (the transverse) placed laterally. In this way two **vertebral grooves** are formed which lie between the central and lateral ridges. The floor of each groove is formed by the laminæ and articular processes, and in these grooves are lodged the muscles which serve to support and control the movements of the column.

Further, the column so constituted is seen to display certain **curves** in an antero-posterior direction. These curves are, of course, subject to very great variation according to the position of the trunk and head, and can only be satisfactorily studied in a fresh specimen; but if care be exercised in the articulation of the vertebræ, the following characteristic features may be observed, assuming, of course, that the column is erect and the head so placed that the axis of vision is directed towards the horizon. There is a forward curve in the cervical region, which gradually merges with the backward thoracic curve; this becomes continuous below with an anterior convexity in the lumbar region, which ends more or less abruptly at the union of the fifth lumbar with the first sacral vertebra, where the sacrum slopes suddenly backwards, causing the column to form a marked projection—the **sacro-vertebral angle**. Below this, the anterior concavity of the front of the sacrum is directed downwards as well as forwards. Of these four curves, two—the thoracic and sacral—are primary, they alone exist during fœtal life; whilst the cervical and lumbar forward curves only make their appearance after birth—the former being associated with the extension and elevation of the head, whilst the latter is developed in connexion with the use of the hind limb in the hyper-extended position, which in man is correlated with the assumption of the erect posture; this curve, therefore, only appears after the child has begun to walk. For these reasons the cervical and lumbar curves are described as secondary and compensatory.

Not infrequently there is a slight **lateral curvature** in the thoracic region, the convexity of the curve being usually directed towards the right side. This may

be associated with a greater use of the muscles of the right upper limb, or may depend on the pressure exercised by the upper part of the thoracic aorta on the vertebræ of the thoracic region, thus causing a slight lateral displacement, together with a flattening of the side of the five thoracic vertebræ (impressio aortica) as was first pointed out by Wood (*Journ. Anat. and Physiol.* vol. iii.) Above and below this curve there are slight compensatory curves in the opposite direction.

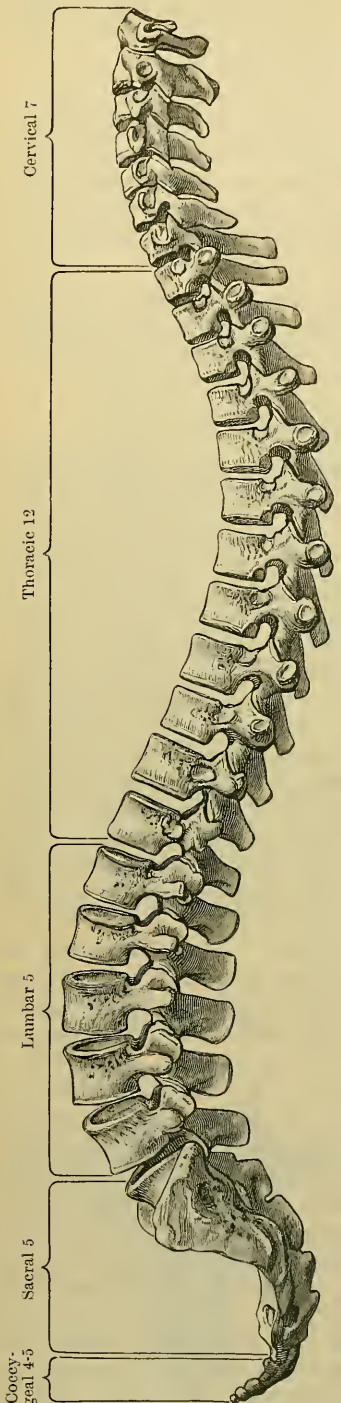


Fig. 68.—Vertebral Column from the Left Side.

The line which unites the tips of the spines is not a repetition of the curves formed by the bodies. This is due to the fact that the length and direction of the spines vary much in different regions; thus in the neck, with the exception of the second, sixth, and seventh, the spines are all short (absent in the case of the atlas). In the thoracic region the spines, though long, are obliquely placed—a circumstance which much reduces their prominence; that of the seventh thoracic vertebra is usually the longest and most slanting. Below this point the length of the spines gradually decreases, and their position more nearly approaches the horizontal. In the loins the spines have all a slight downward direction.

Taken as a whole, the spines of the movable vertebræ in man have a downward inclination—a character which he shares with the anthropoid apes and a few other animals. This character serves to distinguish his column from those of lower mammals in which the spines of the lumbar vertebræ are directed headwards towards the "centre of motion," which is usually situated near the hinder extremity of the thorax, where a vertebra is placed the direction of whose spine is vertical to the horizontally disposed column; this vertebra is often referred to as the **anticlinal vertebra.**

The spines of the upper three or four sacral vertebræ form an osseous ridge with interrupted tubercles. The ridge formed by the vertebral spines is an important determinant of the surface form, as it corresponds to the median furrow of the back, and here the individual spines may be felt and counted from the seventh cervical down to the sacral region. This is best done when the back is well bent forwards.

As viewed from the front, the vertebral bodies increase in width from the second cervical to the first thoracic; thence a reduction in breadth takes place to the level of the fourth thoracic, below which there is a gradual increase in their transverse diameters until the sacrum is reached. Here a rapid reduction in width takes place, terminating inferiorly in the nodules of the coccyx.

The transverse processes of the atlas are wide and outstanding. The succeeding four cervical vertebræ have transverse processes of nearly equal width; the seventh, however, displays a marked increase in its transverse diameter, and is about equal in width to the first thoracic vertebra. Below this a gradual and regular diminution in width characterises the transverse processes of the thoracic vertebræ, until in the case of the eleventh and twelfth they are merely represented by the small external tubercles. In the lumbar region the transverse processes again appear outstanding, and of nearly equal length.

The transverse diameter of the lateral mass of the first sacral vertebra forms

the widest part of the column. Below this a decrease in width occurs until the level of the third sacral segment is reached, at which point the transverse diameter is somewhat abruptly diminished, a reduction in width which is further suddenly accentuated opposite the fifth sacral segment.

As viewed from the side, the bodies display a gradual increase in their antero-posterior width until the second lumbar vertebra is reached, below which this diameter is slightly reduced. In the sacral region the reduction in this diameter is great in the first and second sacral segments, more gradual and less marked in the last three segments.

The facets for the heads of the ribs in the upper thoracic region lie on the sides of the bodies; those for the tenth, eleventh, and twelfth are placed farther back on the pedicles.

The **intervertebral foramina** increase in size from above downwards in the movable part of the column, being largest in the lumbar region. In the sacral region they decrease in size from above downwards. In the cervical region the two highest cervical nerves pass out behind the articular processes of the atlas and axis, and lie, therefore, behind the corresponding transverse processes of these vertebræ. The succeeding cervical nerves pass out through the intervertebral foramina which are placed between the transverse processes and in front of the articular processes. In the thoracic and lumbar vertebræ the intervertebral foramina lie in front of both the articular and transverse processes. The arrangement of these foramina in the sacrum has been already sufficiently explained.

The **neural canal** for the lodgment of the spinal cord and its meninges is largest in the cervical and lumbar regions, in both of which it assumes a triangular form; whilst it is narrow and circular in the thoracic region. These facts are correlated with the movements of the column which are most free in those regions where the canal is largest, *i.e.* the neck and loins.

The **average length** of the vertebral column is from 70 to 73 centimetres, or from $27\frac{1}{2}$ to $28\frac{3}{4}$ inches. Of this the cervical part measures from 13 to 14 cm.; the thoracic, 27 to 29 cm.; lumbar, 17 to 18 cm.; and the sacro-coccygeal, 12 to 15 cm. The individual differences in the length of the column are less than one might expect, the variation in height of different individuals being often largely dependent on the length of the lower limbs. In the female the average length of the column is about 60 centimetres, or $23\frac{3}{4}$ inches, and the curve in the lumbar region is usually more pronounced.

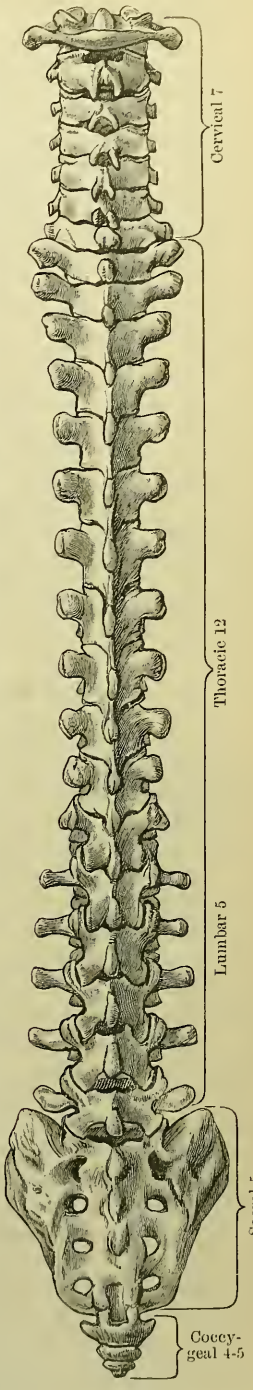


FIG. 69.—VERTEBRAL COLUMN AS SEEN FROM BEHIND.

Architecture.—The vertebræ are formed of spongy bone confined within a thin and dense envelope. In the bodies the arrangement of the cancellous tissue, which is traversed by venous channels, is such as to display a vertical striation with lamellæ arranged horizontally. The external, superior, and inferior walls are very thin—that directed to the neural canal being usually thicker and denser than the others. In the pedicles and roots of the transverse processes the cancellous tissue is much more open. The outer envelope is much thicker where it bounds the neural ring, and where it forms the bottom of the superior and inferior intervertebral notches. In the laminæ the spongy tissue is confined between two compact layers, of which that directed to the spinal canal is the thicker. In the spinous processes the upper edge is always the more compact.

Variations.—**Numerical Variations of the Column as a Whole.**—Increase in the number of vertebral segments is usually due to differences in the number of the coccygeal vertebræ; these

may vary from four—which may be regarded as the normal number—to six. The number of presacral or movable vertebræ is normally 24 (7 C, 12 D, and 5 L). In which case the 25th vertebra forms the first sacral segment (vertebra fulcralis of Welcker). The number of presacral vertebræ may be increased by the intercalation of a segment either in the thoracic or lumbar region without any alteration in the number of the sacral or coccygeal elements: thus we may have 7 C, 13 D, and 5 L, or 7 C, 12 D, and 6 L, or may be reduced by the disappearance of a vertebral segment—thus, 7 C, 12 D, and 4 L. Such an arrangement presupposes developmental errors either of excess or default in the segmentation of the column. On the other hand, the total number of vertebral segments remaining the same (24 or 25), we may have variations in the number of those assigned to different regions due to the addition of a vertebral segment to one, and its consequent subtraction from another region. Thus, in the 24 presacral vertebræ, in cases of the occurrence of cervical ribs the formula is rearranged thus—6 C, 13 D, and 5 L, or, in the case of a thirteenth rib being present, the formula would be 7 C, 13 D, 4 L, as happens normally in the gorilla and chimpanzee. Similarly, the number of the presacral vertebræ (24) may be increased by the withdrawal of a segment from the sacral region—7 C, 12 D, 6 L, and 4 S—or diminished by an increase in the number of the sacral vertebræ, as in the formula 7 C, 12 D, 4 L, and 6 S. Increase in the number of sacral segments may be due to fusion with a lumbar vertebræ, or by the addition of a coccygeal element: the latter is more frequently the case. This variability in the constitution of the sacrum is necessarily correlated with a shifting backwards and forwards of the pelvic girdle along the vertebral column. Rosenburg considers that the 26th, 27th, and 28th vertebræ are the primitive sacral segments, and that the sacral characters of the 25th vertebræ (the first sacral segment in the normal adult column) are only secondarily acquired. He thus supposes that during development there is a forward shifting of the sacrum and pelvic girdle, with a consequent reduction in the length of the presacral portion of the column. This view is opposed by Paterson (*Roy. Dublin Soc. Scientific Trans.* vol. v. Ser. II.), who found that ossification took place in the alæ of the 25th vertebra (first adult sacral segment) before it made its appearance in the alæ of the 26th vertebra. He thus assumes that the alæ of the 25th vertebra may be regarded as the main and primary attachment with the ilium. His conclusions, based on a large number of observations, are at variance with Rosenburg's views, for, according to his opinion, liberation of the first sacral segment is more common than assimilation with the fifth lumbar vertebra, and assimilation of the first coccygeal vertebra with the sacrum is more common than liberation of the fifth sacral, thus leading to the inference that the sacrum tends to shift backwards more often than forwards. (See also T. Dwight, *Anat. Anz. Jena*, vol. xix. pp. 321, 337.)

THE CARTILAGINOUS VERTEBRAL COLUMN.

As has been already stated (p. 30), the neural tube and the notochord are enveloped by a continuous sheath of mesodermal tissue which forms the **membranous vertebral column.** It is by the chondrification of this that the cartilaginous column is developed. This process commences about the end of the first or the beginning of the second month of fœtal life. In correspondence with each vertebral segment, two symmetrical nodules of cartilage appear on either side of the notochord; these rapidly surround and constrict it. By their fusion they constitute the body of a cartilaginous vertebra, and are so disposed that they alternate in position with the muscle plates which are lying on either side. In this way a vertebral body corresponds in position to the posterior half of the anterior myotome, and the anterior half of the posterior myotome, the intermyotomic intervals, which contain the connective tissue plates separating the muscle segments, lie in line laterally with the mid-points of the sides of the cartilaginous vertebræ. It is by chondrification of these intersegmental layers that in certain regions the ribs are ultimately developed. Meanwhile, the scleratogenous tissue between the chondrifying vertebral bodies undergoes little change and persists as the intervertebral disc. Here the embedded chorda undergoes but slight compression and enlarges, so that if a length of the column be examined in longitudinal section the notochord displays a moniliform appearance, the constricted parts of the chorda corresponding to the bodies, the enlarged portions to the discs. The former disappear at a later stage when ossification begins, but the latter persist in the adult as the pulpy core in the centre of the intervertebral disc.

The portions of the scleratogenous tissue which lie lateral to the chorda have next to be considered; these extend dorsalwards around the neural canal, and ventralwards beneath the chorda. The former is sometimes called the vertebral bow, the latter the hypochordal bow. The vertebral bow begins to chondrify on either side, and forms the lateral portions of the cartilaginous neural arch, the extremities of which usually unite dorsally about the fourth month of fœtal life; if from defective development this union should fail to occur, a deformity known as spina bifida is the result.

From the cartilaginous neural arch so formed arise the chondrified rudiments of the spinous, transverse, and articular processes.

The chondrification of the neural arch is variously described as being independent of the body or an extension from it; in any case, union between it and the body is rapidly effected.

The scleratogenous tissue between the cartilaginous neural arches which does not undergo chondrification persists as the ligaments uniting the neural laminæ.

As regards the so-called hypochordal bow, for the most part it disappears. By some it is regarded as being represented by a fibrous strand in the intervertebral disc in front of the vertebra to which it belongs. It is, however, noteworthy that in the case of the atlas vertebra there is an exception to this arrangement; for here the hypochordal bow chrondrifies and subsequently by ossification forms the anterior arch of that bone—an arch which lies ventral to, and embraces the odontoid process of the axis (*q.v.* p. 92).

It is only in the thoracic region that the ribs, developed as stated above by the chondrification of the intersegmental septa, attain their full dimensions. In the cervical, lumbar, and sacral regions they exist only in a rudimentary or modified form, as has been described elsewhere. In the construction of the chest wall the ribs are supported ventrally by the sternum, as to the development of which there is some difference of opinion. Ruge has described this bone as formed by the fusion of two cartilaginous bands produced by the coalescence of the expanded ends of the first five or seven cartilaginous ribs. Paterson, on the other hand, regards the sternum as arising independently of the ribs by the union of a right and left sternal bar in the median ventral line. There are also reasons for supposing that the presternum is intimately associated with the development of the ventral part of the shoulder girdle.

Ossification of the Vertebræ.—The vertebræ are developed by ossification of the cartilage which surrounds the notochord and which passes backwards over the sides of the neural canal. The centres for the bodies first appear in the lower thoracic vertebræ about the tenth week. An oval nucleus develops in each body. At first it is placed dorsal to the notochord, but subsequently surrounds and causes the disappearance of that structure. Occasionally, however, the primitive centre appears to be formed by the coalescence of two primary nuclei. Support is given to this view by the occasional occurrence of vertebræ in which the body is developed in two lateral halves, or in cases where only one-half of the body persists (Turner); normally, however, it is impossible to make out this division. From these single nuclei the bodies are developed, the process extending up and down the column until, by the fifth month, all the centra possess ossific deposits, except the coccygeal segments. About the seventh week a single centre appears in the neural arch on either side. These commence first to ossify in the upper cervical region and extend rapidly downwards throughout the column. They first appear near the bases of the superior articular processes, and extend backwards into the laminæ, outwards into the transverse processes, and forwards into the pedicles. These latter project anteriorly, and form a considerable portion of the postero-lateral aspects of the body, from which, however, they are separated by a cartilaginous strip—the neuro-central synchondrosis—which does not entirely disappear until about the fifth or sixth year. It is important to note that in the thoracic region the costal facets lie behind the neuro-central synchondrosis, and are therefore borne on the lateral aspects of the pedicles. Fusion of the laminæ in the mesial plane behind begins, after birth, in the lumbar region and extends upwards, so that by the fifteenth month or thereabouts the arches in the cervical region are completed behind. In the sacral region ossification is slower, the spinal canal not being enclosed till the seventh to the tenth year. The spinous processes are cartilaginous at birth, but these become ossified by the extension into them of the bony laminæ.

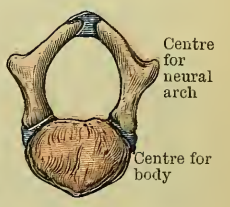


Fig 70.—Ossification of Vertebræ.

At puberty certain **secondary centres** or **epiphyses** make their appearance; these are five in number. One caps the summit of the spinous process, except in the cervical region. A single epiphysis on either side appears at the extremity of the transverse process, and in the thoracic region assists in forming the articular surface for the tubercle of the rib. Two epiphysial plates are formed—one for the upper, and the second for the

lower surface of the body, including also that part which lies behind the neuro-central synchondrosis and formed by the pedicle; from these the thickened circumference of both upper and lower aspects of the body are derived. Fusion of these centres with the rest of the bone is not complete till the twenty-fifth year.

In the cervical region independent centres are described as occurring in the anterior roots of the transverse processes of the sixth and seventh vertebræ. These correspond to the costal element, and may occasionally persist in the form of cervical ribs. Elsewhere they are formed by lateral extensions from the pedicle.

In the lumbar region the transverse process of the first lumbar vertebra is occasionally associated with an independent costal centre, which may blend with it, or persist as a

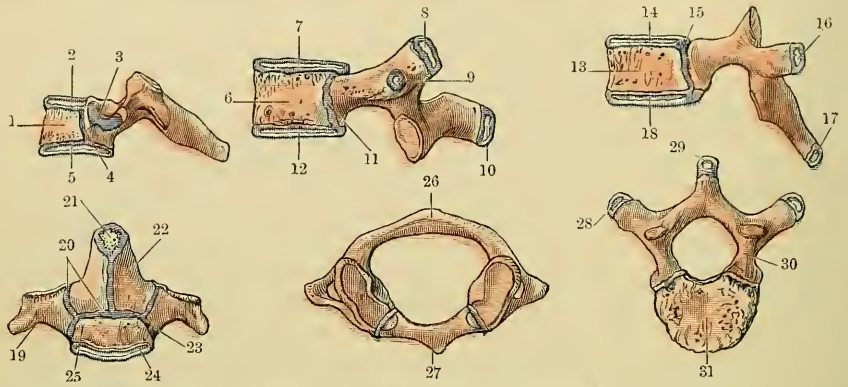


FIG. 71.—OSSIFICATION OF VERTEBRÆ.

Cervical vertebra.

1. Centre for body.
2. Superior epiphysial plate.
3. Anterior bar of transverse process developed by lateral extension from pedicle.
4. Neuro-central synchondrosis.
5. Inferior epiphysial plate.

Lumbar vertebra.

6. Body.
7. Superior epiphysial plate.
8. Epiphysis for mammillary process.
9. Epiphysis for transverse process.
10. Epiphysis for spine.
11. Neuro-central synchondrosis.
12. Inferior epiphysial plate.

Dorsal vertebra.

13. Centre for body.
14. Superior epiphysial plate, appears about puberty; unites at 25th year.
15. Neuro-central synchondrosis does not ossify till 5th or 6th year.
16. Appears at puberty; unites at 25th year.
17. Appears at puberty; unites at 25th year.
18. Appears about 6th week.

Axis.

19. Centre for transverse process and neural arch; appears about 8th week.
20. Synchondroses close about 3rd year.
21. Centre for summit of odontoid process; appears 3rd to 5th year, fuses 8th to 12th year.
22. Appears about 5th or 6th month; unites with opposite side 7th to 8th month.
23. Synchondrosis closes from 4th to 6th year.
24. Inferior epiphysial plate; appears about puberty, unites about 25th year.
25. Single or double centre for body; appears about 5th month.

Atlas.

26. Posterior arch and lateral masses developed from a single centre on either side, which appears about 7th week.
27. Anterior arch and portion of superior articular surface developed from single or double centre, appearing during 1st year.

Dorsal vertebra.

28. Epiphysis for transverse process; appears about puberty, unites about 25th year.
29. Epiphysis appears about puberty; unites about 25th or 27th year.
30. Centre for neural arch on either side; appears about 6th or 7th week, the laminæ unite from birth to 15th month.
31. Centre for body; appears about 6th week, unites with neural arch from 5th to 6th year.

lumbar rib. The mammillary processes are derived from separate epiphyses. The neural arch of the fifth lumbar vertebra is occasionally developed from two centres on either side, as is demonstrated by the fact that the arch is sometimes divided by a synchondrodial joint running obliquely across between the superior and inferior articular processes on either side. (See *ante*, p. 83; also *Fortschritte auf dem Gebiete der Röntgenstrahlen.* Ergänzungsheft i.; "die Entwickelung des menschlichen Knochengerüstes während des fötalen Lebens," von Lambertz.)

Atlas.—The lateral masses and posterior arch are developed from two centres—one on either side—which correspond with the centres from which the neural arches of the other members of the series are developed. These make their appearance about the seventh week, and do not unite posteriorly till after the third year. Their point of union is sometimes preceded by the formation of a distinct spinal nucleus (Quain). The anterior

arch is developed from centres variously described as single or double, which appear in one of the hypochordal arches of cartilage described by Froriep (*Arch. f. Anat. u. Physiol., Anat. Abth.* 1886) which here persists. In this cartilage ossification commences during the first year of life. Union with the lateral masses is delayed till six or eight years after birth. The external extremities of the anterior arch assist in forming the fore part of the superior articular processes.

Axis.—The axis ossifies from five primitive centres. Of these, two—one on either side—appear about the seventh week, and form the articular and transverse processes, together with the laminæ and spine. One, or it may be two, nuclei appear in the lower part of the body about the fifth month. The upper part of the body, including a small part of the superior articular process, and the base of the odontoid process, are developed from two laterally-placed nuclei which appear shortly after, and fuse together at the seventh or eighth month, so that at birth the bone consists of four pieces. Fusion between these parts takes place in the following order:—The odontoid unites with the body and lateral parts about the third or fourth year; union between the two lateral portions posteriorly and the body and lateral parts in front, is complete at from four to six years.

The summit of the odontoid process is developed from a separate centre, occasionally double, which appears from the third to the fifth year, and fuses with the rest of the bone from the eighth to the twelfth year. About puberty an annular epiphysis is developed on the under surface of the body, with which it is completely united during the twentieth to the twenty-fifth year. Some authorities state that a few granules between the base of the odontoid and the upper surface of the body represent the superior epiphysial plate; but as fusion between the odontoid and the body occurs before the time for the appearance of these secondary epiphysial plates, this can hardly be regarded as correct. The line of fusion of the odontoid with the body is defined by a small disc of cartilage which persists within the substance of the bone till an advanced period of life.

A pair of epiphyses placed over the tubercles of the spine, if not always present, are at least frequent.

Sacrum.—Each of the sacral segments is ossified from three centres: one for the body, and two for the neural arch—that for the body, which makes its appearance in the first three sacral vertebræ about the end of the third month, about the fifth to the eighth month for the last two segments. From the two centres for the neural arches, which make their appearance about the fifth or sixth month in the higher segments, the laminæ, articular processes, and the posterior half of the alæ on either side are developed. The spinal canal is not enclosed till the seventh to the tenth year, the laminæ usually failing to meet in the lowest segment, and occasionally, to a greater or less extent, in some of the higher segments. The anterior part of the lateral masses is developed from separate centres which represent the costal elements (Gegenbauer). These appear about the sixth to the eighth month, and may develop in relation to the upper four sacral segments; more usually they are met with in connexion with the first three, and exceptionally they may be found only in the upper two. It is by fusion of these with the posterior arches that the lateral masses which support the innominate bones are formed. The costal elements fuse about the second to the fifth year with the neural arches, prior to their union with the centra; and the segments of the lateral masses unite with each other sooner than the union of the bodies is effected. The latter only takes place after puberty by the fusion of the epiphysial plates, a pair of which make their appearance between the centra of each segment. The lower segments begin to unite together about the eighteenth year, but fusion between the first and second sacral vertebræ is not completed till the twenty-fifth year or after. In addition to the foregoing, two thin osseous laminæ are developed in the cartilage covering the outer surface of the alar mass. The upper of these overspreads the auricular surface, whilst the lower forms the sharp edge below. The extremities of the upper spinous processes are occasionally developed from independent epiphyses. On making a mesial section of an adult bone the persistence of the intervertebral discs between the centra is indicated by a series of oval cavities.

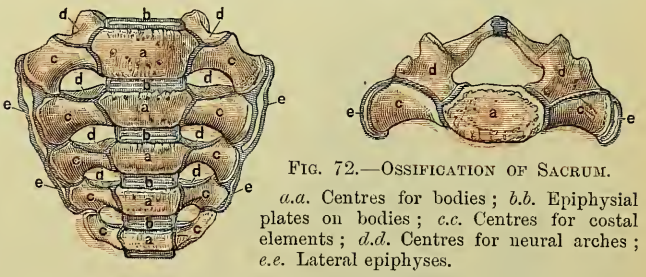


FIG. 72.—OSSIFICATION OF SACRUM.

a.a. Centres for bodies; *b.b.* Epiphysial plates on bodies; *c.c.* Centres for costal elements; *d.d.* Centres for neural arches; *e.e.* Lateral epiphyses.

Coccygeal Vertebræ.—These are cartilaginous at birth. Each has a separate centre; the first appears from the first to the fourth year, the second from the sixth to the tenth year, the third and fourth segments at or about puberty. Secondary centres, for the coccygeal cornua and epiphysial plates for the bodies are also described. Fusion of the various segments begins below and proceeds upwards, but is liable to great individual variation. In advanced life the coccyx is often ossified to the sacrum.

SERIAL HOMOLOGIES OF THE VERTEBRÆ.

It is a self-evident fact that the vertebral column consists of a number of segments or vertebræ all possessing some characters in common. These vertebræ or segments undergo modifications according to the region they occupy and the functions they are called upon to serve, so that their correspondence and identity is thereby obscured. There is no difficulty in recognising the homology of the bodies and neural arches throughout the column. According to some anatomists the neural arch is the more primitive element in the formation of a vertebra, whilst others hold that the centra are the foundation of the column. Be that as it may, we find that in the higher vertebrates, at least, the bodies are the parts which most persist. They are, however, subject to modifications dependent on their fusion with one another. This occurs in the cervical part of the column where the centrum of the first cervical or atlas vertebra has for functional reasons become fused with the body of the second or axis vertebra to form the odontoid process of that segment. For similar reasons, and in association with the union of the girdle of the hind-limb with the column, the bodies of the vertebræ which correspond to the sacral segment become fused together to form a solid mass. In the terminal portion of the caudal region the centra alone represent the vertebral segments.

As regards the neural arch, this in man becomes deficient in the lower sacral region, and absent altogether in the lower coccygeal segments. The spinous processes are absent in the case of the first cervical, lower sacral, and all the coccygeal vertebræ, and display characteristic differences in the cervical, thoracic, and lumbar regions, which have been already described. The articular processes (zygapophyses) are secondary developments, and display great diversity of form, determined by their functional requirements. It is noteworthy that, in the case of the upper two cervical vertebræ, they are so disposed as to lie in front of the foramina of exit of the upper two spinal nerves, and by this arrangement the weight of the head is transmitted to the solid column formed by the vertebral bodies, and not on to the series of neural arches. It is in regard to the homology of the transverse processes, so called, that most difficulty arises. In the thoracic region they can best be studied in their simplest form; here the ribs—which Gegenbauer regards as a differentiation from the inferior or hæmal arches, in opposition to the view advanced by others that they are a secondary development from the fibrous intermuscular septa—articulate with the transverse processes and bodies of the thoracic vertebræ through the agency of the tubercular (diapophysis) and capitular (parapophysis) processes respectively, the latter being placed, strictly speaking, on the neural arch behind the line of the neuro-central synchondrosis.

An interval is thus left between the neck of the rib and the front of the transverse process; this forms an arterial passage which corresponds to the vertebrarterial canal in the transverse processes of the cervical vertebræ, the anterior bar of which is homologous with the head and tubercle of the thoracic rib, whilst the posterior part lies in series with the thoracic transverse process. These homologies are further emphasised by the fact that in the case of the seventh cervical vertebra the anterior limb of the so-called transverse process is developed from an independent ossific centre, which occasionally persists in an independent form as a cervical rib.

In the lumbar region the external or transverse process is serially homologous with the thoracic ribs, though here, owing to the coalescence of the contiguous parts, there is no arterial channel between the rib element and the true transverse process, which is represented by the accessory processes (anapophysis), placed posteriorly at the root of the so-called transverse process of human anatomy. Support is given to this view by the presence of a distinct costal element in connexion with the transverse process of the first lumbar vertebra, which accounts for the occasional formation of a supernumerary rib in this region. The cases of foramina in the transverse processes of the lumbar vertebræ (see p. 83) are also noteworthy as supporting this view.

In the sacrum the lateral mass of the bone is made up of combined transverse and costal elements, with only very exceptionally an intervening arterial channel (see p. 86). In the case of the upper three sacral segments the costal elements are largely developed, assist in supporting the ilia, and are called the true sacral vertebræ; whilst the lower sacral segments, which are not in contact with the ilia, are referred to as the pseudo-sacral vertebræ.

The anterior arch of the atlas vertebra is, according to Froriep, developed from a hypochordal strip of cartilage (hypochordal spange).

THE STERNUM.

The **sternum** or **breast bone** occupies the middle of the upper part of the thoracic wall anteriorly. It is connected laterally with the cartilages of the first seven ribs, and supports, superiorly, the clavicles. It consists of three parts, named respectively the **manubrium** or **presternum**; the **body** (corpus sterni), **gladiolus** or **mesosternum**; and the **ensiform** or **xiphoid cartilage** (processus xiphoideus) or the

metasternum. Of these the body is formed by the fusion in early life of four segments or sternebræ.

The **manubrium**, usually separate throughout life from the rest of the bone, though occasionally fused with it, is of a flattened triangular form. The anterior surface, slightly saddle-shaped, affords attachment to the fibres of the pectoralis major and sterno-mastoid muscles. It is bounded above by a thick border, the lateral parts of which are hollowed out obliquely to form the facets (incisuræ claviculares) for the sternal ends of the clavicles; around the facets, which have an upward, outward, and slightly backward direction, the bone is faintly lipped. In the interval between these two facets there is a slight notch (incisura jugularis) which forms the floor of the characteristic hollow seen at the root of the neck anteriorly—the suprasternal notch, or pit of the neck. The lateral borders are excavated immediately below the clavicular facets for the reception of the cartilages of the first ribs. Below this, the margin of the bone slopes inwards, and is sharp, except inferiorly, where it presents a facet which supports a part of the second costal cartilage. Around this the bone is usually lipped anteriorly. The upper angles correspond to the ridge separating the clavicular facets from the first costal facets: whilst the lower angle, which may be regarded as cut across transversely, forms the surface which is united by cartilage to the body of the sternum. The anterior edge of this surface is usually prominent. The posterior aspect of the manubrium is smoother than the anterior, is pierced by numerous foramina, and is slightly concave from side to side and above downwards. Here are attached some of the fibres of the sterno-hyoid and sterno-thyroid muscles.

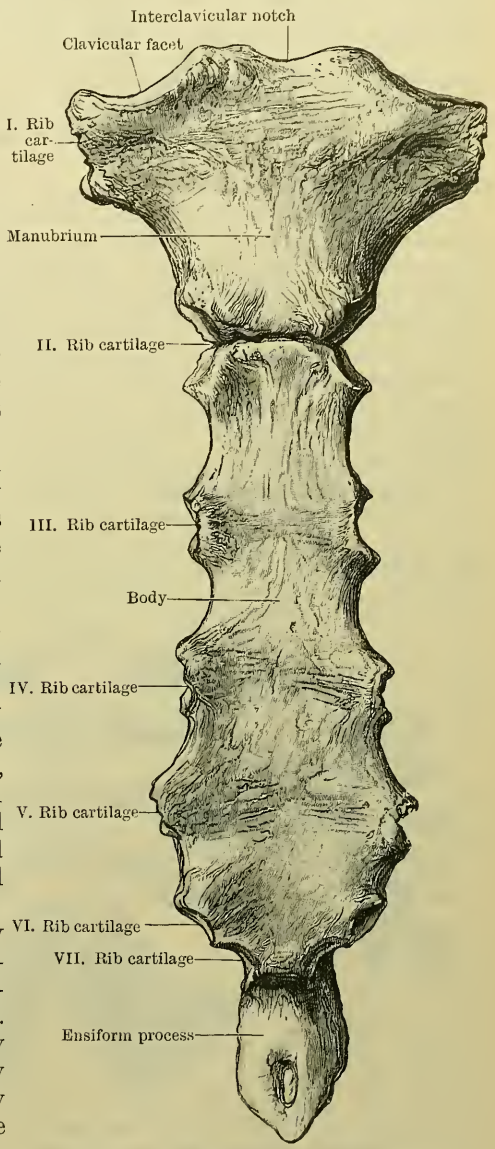


FIG. 73.—THE STERNUM (anterior view).

The **body** (corpus sterni), usually twice the length and from half to two-thirds the width of the manubrium, displays evidence of its composite nature. If the *anterior surface*, which is slightly convex from above downwards, and faintly concave from side to side, be carefully examined, three ill-marked ridges may be seen crossing it transversely; these correspond to the lines of fusion between the four primitive segments. To this surface of the bone the great pectoral muscles are extensively attached on either side of the middle line. The *lateral borders* are thick and interrupted at points corresponding to the transverse lines already mentioned by U-shaped hollows, the edges of which are more or less projecting. These are for the reception of the cartilages of the third, fourth, and fifth ribs. The *upper border* is united to the manubrium above, and forms with it an angle of variable degree—the **sternal angle** (angulus sterni). A small facet is formed at the expense of the outer extremity of this border, and in conjunction with the facet on the lower edge of the manubrium forms a recess on either side, in line with

the angle, into which the cartilage of the second rib fits. The *lower border* of the body is curved, and is united in the middle line with the xiphoid cartilage, whilst on either side it is pitted to receive the cartilages of the sixth and seventh ribs, the latter being in part supported by the xiphoid cartilage. The middle line of the body of the sternum anteriorly corresponds to the floor of the median surface furrow, which runs down the front of the chest in the interval between the two great pectoral muscles. The *posterior surface* is slightly concave from above downwards, and displays faint indications of three transverse lines in correspondence with those placed anteriorly. It is in relation with the pleura and pericardium, and affords attachment at its lower extremity to the triangularis sterni muscle.

The **xiphi-sternum** (processus xiphoideus) displays many varieties of form and structure. It is a pointed process of cartilage, supported by a core of bone connected above with the lower end of the body of the sternum, and having its lower extremity, to which the linea alba is attached, free. It lies somewhat posterior to the plane of the anterior surface of the manubrium, and forms a floor to the V-shaped interval between the cartilages of the seventh ribs. In this way a depression is formed, the surface hollow in correspondence with which is called the pit of the stomach or **infrasternal depression**. To the sides of this process are attached the aponeuroses of the abdominal muscles, whilst posteriorly the fibres of the diaphragm and triangularis sterni muscles derive attachment from it. It remains partly cartilaginous until middle life, at which time it generally undergoes ossification, particularly at its upper part, which becomes fused with the body. Of varied form, it may be met with of spatula-shape, bifid, circular, pierced in the centre, or twisted and deflected to one or other side, or turned forward.

The **sternum as a whole** is broadest above where the first rib cartilages are attached. It becomes narrow opposite the second rib cartilages, but again expands until the level of the fifth rib cartilage is reached, below which it is rapidly reduced in width and ends below in the pointed xiphoid cartilage. Its position in the body is oblique from above downwards and forwards; its axis, if prolonged upwards, would touch the column opposite the third or fourth cervical vertebra. Though liable to changes in position by the rising and falling of the chest wall, its upper extremity corresponds to the level of the lower border of the second dorsal vertebra, whilst the lower end of the xiphoid cartilage usually falls in line with the disc between the tenth and eleventh dorsal vertebræ.

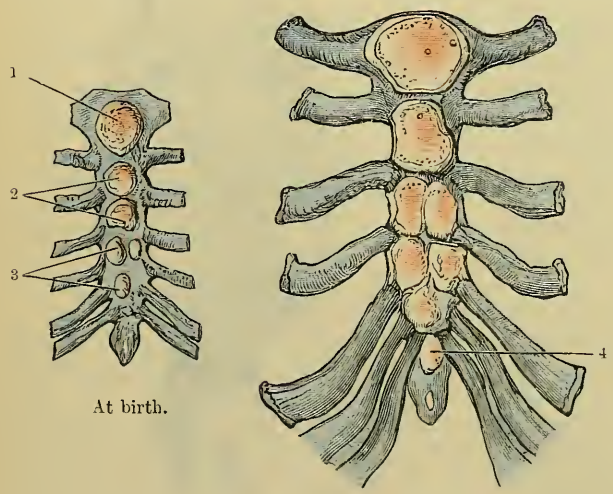


Fig. 74.—Ossification of the Sternum.

In this figure the second as well as the third segment of the body possesses two centres.

1. Appears about 5th or sixth month. 2. Appear about 7th month; unite from 20 to 25. 3. Appear about 8th or ninth month; III. segment unites with II. about puberty; IV. segment unites with III. in early childhood. 4. Appears about 3rd year or later.

In women the sternum is usually narrower and shorter than in men, and its position less oblique.

Architecture.—It consists of large-celled spongy bone, which is highly vascular, and is contained between two layers of thin compact tissue.

Ossification. — The cartilaginous sternum, developed from the fusion mesially of two cartilaginous bands uniting the anterior extremities of the cartilages of the first eight ribs, according to the researches of Ruge and more recently of Eggeling, begins to ossify about the sixth month of fœtal life. About this time a single centre appears in the manubrium; at birth this is well developed. Secondary epiphyses have been described in connexion with the clavicular facets; these do not unite with the rest of

the manubrium till adult life is reached. The body formed by the fusion of four segments is ossified from independent centres, either single or double, for each segment. These appear—the highest as early as the sixth month of intrauterine life—in some cases even before the manubrium has begun to ossify (Lambertz), the lowest towards the end of full term. The common arrangement met with at birth is a single centre for the first, and double centres for each of the succeeding segments. Union between these segments occurs rather irregularly, and is liable to much variation. The fourth unites with the third segment in early childhood, the third with the second about puberty, whilst the fusion of the second with the first segment may not be complete till the twentieth or twenty-fifth year.

The xiphi-sternum usually ossifies from a single centre, which may appear as early as the third year, though often very much later. The xiphi-sternum usually unites with the body about forty or fifty, and in exceptional cases osseous union between the body and manubrium may occur in advanced life.

According to Paterson the presternum is developed in association with the shoulder girdle and becomes only secondarily associated with the ventrally growing ribs.

Variations.—The sternum is liable to considerable individual variations affecting its length and direction. The majority of bones are asymmetrical, displaying irregularities in the levels of the clavicular facets. The higher costal facets may be closer together on one, usually the right side, than the other, whilst the pre-mesosternal joint is often oblique, sloping somewhat to the right. According to Birmingham, these are the result of the strain thrown on the shoulder by pressure either directly applied or through the pull of a weight carried in the hand.

Sometimes the sternum articulates with eight rib cartilages. This may happen on one or both sides, but when unilateral, much more frequently on the right side—a condition by some associated with right-handedness. It is, however, more probably a persistence of the primitive condition of the cartilaginous sternum, in which each half is connected with the anterior extremities of the first eight costal arches. In some rare cases only six pairs of ribs articulate by means of their costal cartilages with the sternum. Recently Lickley has brought forward evidence to show that the seventh rib is undergoing regressive changes. (*Anat. Anz.* vol. xxiv. p. 326.)

Occasionally the presternum supports the first three ribs; in other words, the manubrium has absorbed the highest segment of the body. Keith has pointed out that this is the condition most commonly met with in the gibbon, and regards its occurrence in man as a reversion to the simian type. As far as is at present known, its occurrence seems more common in the lower races. Through errors of development the sternum may be fissured throughout, due to failure of fusion of the cartilaginous hemisterna. The two ossified halves are usually widely separated above, but united together below by an arthrodial joint. The heart and pericardium are thus uncovered by the bone. Occasionally this condition is associated with ectopia cordis, under which circumstances life is rendered impossible. Through defects in ossification the mesosternum may be pierced by a hole, usually in its lower part, or through failure of fusion of the lateral centres one or more of the segments of the body may be divided longitudinally.

Occasionally small ossicles are found in the ligaments of the sterno-clavicular articulation. These are the so-called episternal bones, the morphological significance of which, however, has not yet been satisfactorily determined. They are by some regarded as the homologues of the interclavicle or episternal bone of monotremes.

THE RIBS.

The **ribs** (costæ) of which there are twelve pairs, form a series of curved osseous bands which support the thoracic wall; posteriorly they articulate with the thoracic or dorsal vertebræ, anteriorly each rib is provided with a costal cartilage. The first seven ribs articulate with the sternum by means of their cartilages, and are termed the **true** (costæ veræ) or **vertebro-sternal ribs.** The lower five ribs are not so supported, and are described as the **false ribs** (costæ spuriæ). Of these the eighth, ninth, and tenth are united by their cartilages to the cartilage of the seventh rib, and are called the **vertebro-chondral ribs,** whilst the last two ribs are free at their anterior extremities, and are named the **floating** or **vertebral ribs.**

A **typical rib** consists of a **head** (capitulum costæ), a **neck** (collum costæ), a **tubercle** (tuberculum costæ), and a **shaft** (corpus costæ), on which, near its posterior end, is the **angle** (angulus costæ).

The **head,** placed on the posterior or vertebral end of the bone, is somewhat expanded. Internally its articular surface is wedge-shaped and divided into two parts, an upper and lower, by a ridge or crest (crista capituli), to which the inter-articular ligament is attached. Of these two facets the lower is usually the larger, and articulates with the upper facet on the body of the vertebra in numerical correspondence with it, whilst the upper facet is for the corresponding area on the

lower part of the body of the vertebra above. The head is supported by a more or less constricted bar of bone, the **neck**. This becomes continuous with the shaft externally, at which point there is a well-marked tubercle on its posterior surface. The anterior surface of the neck is smooth; its posterior aspect is rough, and pierced by numerous small holes for vessels. Here is attached the middle costo-transverse ligament. Not uncommonly the upper border of the neck is lipped and ridged (crista colli costæ), and affords attachment to the anterior costo-transverse ligament.

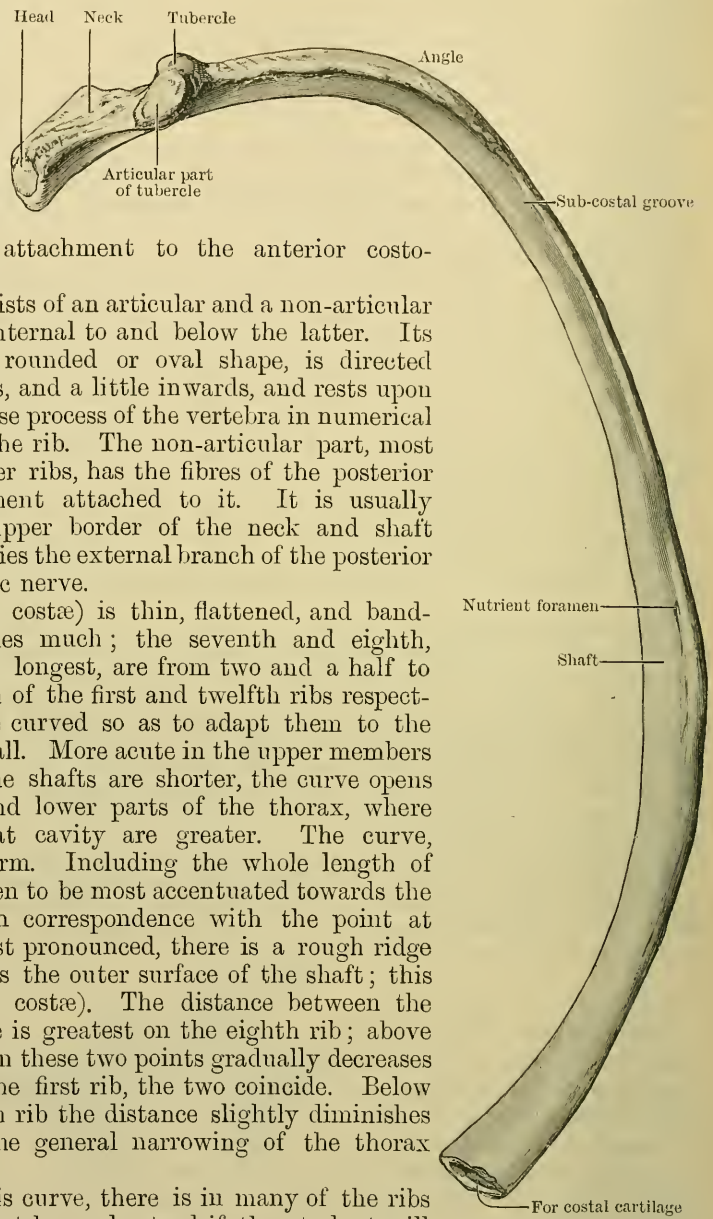


Fig. 75.—Fifth Right Rib as seen from Below.

The **tubercle** consists of an articular and a non-articular part; the former is internal to and below the latter. Its articular surface, of rounded or oval shape, is directed downwards, backwards, and a little inwards, and rests upon a facet on the transverse process of the vertebra in numerical correspondence with the rib. The non-articular part, most prominent in the upper ribs, has the fibres of the posterior costo-transverse ligament attached to it. It is usually separated from the upper border of the neck and shaft by a groove, in which lies the external branch of the posterior division of the thoracic nerve.

The **shaft** (corpus costæ) is thin, flattened, and band-like. Its length varies much; the seventh and eighth, which are usually the longest, are from two and a half to three times the length of the first and twelfth ribs respectively. The shafts are curved so as to adapt them to the form of the thoracic wall. More acute in the upper members of the series, where the shafts are shorter, the curve opens out in the middle and lower parts of the thorax, where the diameters of that cavity are greater. The curve, however, is not uniform. Including the whole length of the bone, it will be seen to be most accentuated towards the hinder part, where, in correspondence with the point at which the bend is most pronounced, there is a rough ridge placed obliquely across the outer surface of the shaft; this is the **angle** (angulus costæ). The distance between the angle and the tubercle is greatest on the eighth rib; above that, the width between these two points gradually decreases until, in the case of the first rib, the two coincide. Below the level of the eighth rib the distance slightly diminishes in conformity with the general narrowing of the thorax below that level.

Combined with this curve, there is in many of the ribs a twist. This may best be understood if the student will take a strip of stiff paper and bend it in the form of the curve of the rib. If, after he has done this, he pulls down the fore end and turns up the hind end of the strip, he will have imparted to the strip of paper a twist similar to that met with in the rib. This appearance is best seen in the middle members of the series, notably in the seventh and eighth ribs, above and below which it gradually becomes less marked. It is the occurrence of this twist which prevents the extremities of the ribs, together with the shaft, from resting on the same plane surface. To this rule there are certain notable exceptions, viz. the first and second, the twelfth, and not infrequently the eleventh.

The shaft has two surfaces, an internal and an external, and two borders, a

superior and an inferior. The external surface, which is smooth, conforms to the general vertical convexity of the thorax, being directed upwards in the first rib, upwards and outwards in the higher ribs, outwards in the middle series, and outwards and slightly downwards in the tenth, eleventh, and twelfth. The internal surfaces are arranged conversely and are covered by the parietal pleura. Towards the sternal end of the middle ribs, where the downward twist is most marked, there is often an oblique line across the outer surface. This is sometimes referred to as the anterior angle. The upper border of the shaft is thick and rounded behind, thinner and sharper in front; to it are attached the fibres of the internal and external intercostal muscles. The lower border is grooved behind at the expense of the inner surface, and is overhung externally by a sharp margin. Anteriorly this **subcostal groove** (sulcus costalis) fades away, and its lips coalesce to form a rounded edge. The intercostal vessels and nerve are lodged in this groove, whilst its lips afford attachment to the external and internal intercostal muscles respectively. On the floor of the groove may also be seen the openings of the canals for the transmission of the nutrient vessels, which are directed towards the vertebral end of the rib.

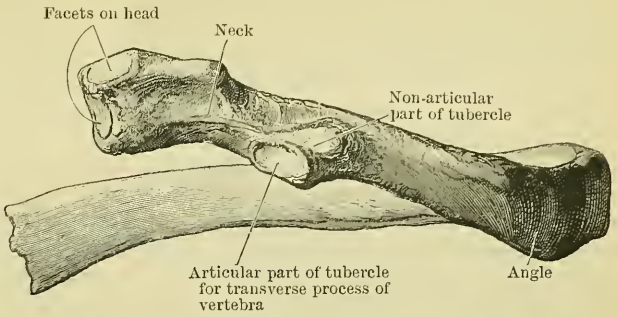


Fig. 76.—Fifth Right Rib as seen from Behind.

The anterior or sternal extremity of the shaft, often slightly enlarged, displays an elongated oval pit into which the costal cartilage is sunk.

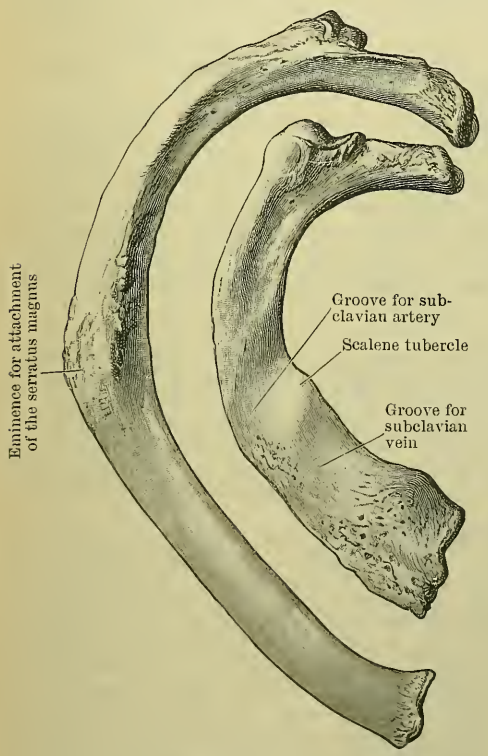


Fig. 77.—First and Second Right Ribs as seen from Above.

Peculiar Ribs.—The first, second, tenth, eleventh, and twelfth ribs all display characters by which they can be readily recognised.

The **first rib** can be easily distinguished from the others by its size, curvature, and flattened form. The **head**, which is of small size, has a single oval or circular facet, which is directed inwards and slightly backwards for articulation with the side of the body of the first thoracic vertebra. The **neck** is flattened from above downwards, and is slightly down-turned towards the end which supports the head. Its anterior border is rounded and smooth; its posterior edge rough for the attachment of ligaments. At the point where the neck joins the shaft posteriorly, a prominent **tubercle** curves upwards and backwards. The inner and under surface of this process has a small circular facet which rests on a corresponding articular surface on the transverse process of the first thoracic vertebra. The **angle** coincides with the tubercle, and thus assists in emphasising its prominence. The surfaces of the body of the rib are directed upwards and downwards, its borders inwards and outwards. If the finger be run along the thin inner border, a distinct spine or tubercle can be readily

felt about an inch or an inch and a quarter from its anterior extremity. This is the **scalene tubercle** (tuberculum scaleni) for the attachment of the scalenus anticus muscle. There is a shallow, oblique groove crossing the upper surface of the shaft in front of this for the lodgment of the subclavian vein; whilst behind the tubercle there is another groove, usually better marked, and passing obliquely forwards for the subclavian artery (sulcus subclaviæ). The space on the upper surface of the rib between this latter groove and the tubercle posteriorly is somewhat rough, and affords attachment to the fibres of the scalenus medius muscle. The anterior extremity of the rib is thickened and often expanded for the reception of its costal cartilage, which is not infrequently ossified. The under surface of the rib is smooth and is covered by pleura. The outer convex border, thin in front, is usually thick and rough behind the subclavian groove, where it has attached to it the fibres of the first digitation of the serratus magnus. Along this edge, also, are attached the external and internal intercostal muscles of the first intercostal space. The inner concave border is thin, and has connected with it the aponeurotic expansion known as Sibson's fascia.

The **second rib** may be distinguished by the size of its curve; the absence of any twist on its shaft, so that it can be laid flat on the table; the oblique direction of the surfaces of its shaft, the outer being directed upwards and outwards, whilst the inner is turned downwards and inwards; and the presence of a well-marked, rough, oval area about the middle of its outer surface and lower border for part of the first, and the whole of the second digitation of the serratus magnus muscle. The head has two facets, and the angle is close to the tubercle posteriorly.

The **tenth rib** has usually only a single articular facet on the head, and may or may not have a facet on the tubercle.

The **eleventh** and **twelfth ribs** are recognised by their length. Their heads, usually large in proportion to their shafts, support a single facet for articulation with the eleventh and twelfth dorsal vertebræ respectively. The tubercles are ill-developed and have no articular facets. The angle is faintly marked on the eleventh, scarcely perceptible on the twelfth. Their anterior extremities are narrow and pointed and tipped with cartilage. The subcostal groove is absent in the twelfth, and but slightly seen in the eleventh. The twelfth is considerably shorter than the eleventh rib.

Architecture.—Each rib consists of a curved and flattened bar of bone, the interior of which is loose and cancellous, whilst the investing envelope is compact. The inner table is much the stronger, attaining its maximum thickness opposite the angle—in front and behind which it becomes gradually reduced. The outer table, much thinner, is stoutest opposite the angle; on the posterior surface of the tubercle and neck it forms but a thin layer. The compact layers forming the upper and lower borders are not so thick as those forming the inner and outer surfaces. The cancellous tissue, loose and open in the shaft, is most compact in the region of the head and towards the anterior extremity.

Variations.—The **number of ribs** may be increased or diminished. Increase may occur by the addition of a cervical rib due to the independent development of the costal element in the transverse process of the seventh cervical vertebra. This may happen on one or both sides. The range of development of these cervical ribs varies; they may unite in front with the sternum, or they may be fused anteriorly with the cartilage of the first rib, or the cervical rib may be free. It may in some instances be represented mainly by a ligamentous band, or its vertebral and sternal ends may be alone developed, the intermediate part being fibrous. At times the vertebral end only may be formed and may be fused with the first rib, thus leading to the formation of a bicipital rib such as occurs in many cetaceans. Increase in the number of ribs may also be due to the ossification of the costal element which is normally present in the embryo in connexion with the first lumbar vertebra. (Rosenberg, *Morph. Jahrb.* i.) Reduction in the number of ribs is less common. The twelfth rib rarely aborts; in some cases the first rib is rudimentary. Cases of congenital absence of some of the ribs have been recorded by Hutchinson, Murray, and Ludeke.

Fusion of adjacent ribs may occur. (Lane, *Guy's Hosp. Reports*, 1883.)

Variations in form may be in great part due to the occupation of the individual and the constricting influence of corsets. Independently of these influences, the fore part of the shaft is sometimes cleft so as to appear double; at other times the cleft may be incomplete so as to form a perforation. Occasionally adjacent ribs are united towards their posterior part by processes having an intermediate ossicle between (Meckel), thus recalling the condition normally met with in birds; more usually, however, the bony projections are not in contact.

The number of true or vertebro-sternal ribs may be reduced to six, or increased to eight (see *ante*, p. 97).

Ossification.—Ossification begins in the cartilaginous ribs about the sixth week, and rapidly extends along the shaft, so that by the end of the third month it has reached the permanent costal cartilage. The sixth and seventh ribs are the earliest to ossify; the first rib being the last (Lambertz). At puberty, or before, secondary centres appear. Of these there are three—an epiphysis for the articular surface of the tubercle, one for the non-articular part of the same process, and one for the head. By the twenty-fifth year fusion between these and the shaft is complete.

THE COSTAL CARTILAGES.

The **costal cartilages**, of which there are twelve pairs, are bars of hyaline cartilage united to the anterior extremities of the ribs, into which they are recessed and held in position by the periosteum. Through these cartilages the first seven ribs are connected directly with the sternum by means of synovial joints corresponding to the notches along the margins of the breast bone. To this there is an exception in the case of the first rib, the cartilage of which is directly blended with the manubrium sterni. The eighth, ninth, and tenth are connected indirectly with the sternum by their union with each other, and their articulation, through the medium of the eighth, with the seventh rib cartilage, whilst the eleventh and twelfth cartilages tip the ribs to which they belong, and lie free in the muscles of the flank. The costal cartilages increase in length from the first to the seventh, below which they become shorter. The first inclines obliquely downwards and inwards to unite with the upper angles of the manubrium. The second lies more or less horizontally. The third to the seventh gradually become more and more curved, inclining downward from the extremities of their respective ribs, and then turning upwards to reach the sternum. The tenth cartilage articulates by means of a synovial joint with the ninth, the ninth with the eighth, and the eighth with the seventh. There are also surfaces for the articulation of the seventh with the sixth, and sometimes for the sixth with the fifth.

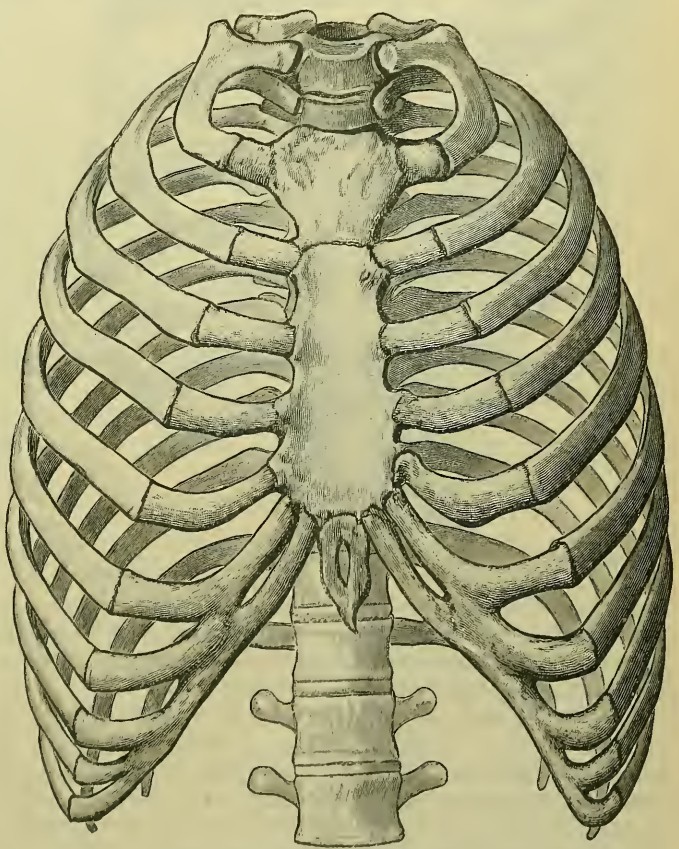


Fig. 78.—The Thorax as seen from the Front.

Variations. — Occasionally a costal cartilage is unduly broad, and may be pierced by a foramen. The number of costal cartilages connected with the sternum may be reduced to six or increased to eight (see p. 97). In advanced life there is a tendency towards ossification in the layers underlying the perichondrium, more particularly in the case of the first rib cartilage, in which it may be regarded as a more or less normal occurrence.

THE THORAX AS A WHOLE.

The bony and cartilaginous thorax is barrel-shaped, being narrower above than below, and compressed from before backwards. Its posterior wall is longer than its

anterior, and its transverse width, which reaches its maximum opposite the eighth or ninth rib, is much in excess of its sagittal diameter. This is largely owing to the forward projection of the thoracic part of the vertebral column into the thoracic cavity.

The **anterior wall** is formed by the ribs and rib cartilages, together with the sternum. The **posterior wall** comprises the thoracic part of the vertebral column and the ribs as far as their angles. Owing to the backward curve of the ribs, and the projection forwards of the vertebral bodies, the antero-posterior diameter of the thoracic cavity is considerably greater on either side of the middle line than in the mesial plane, thus allowing for the lodgment of the rounded posterior borders of the lungs. For the same reason the furrow on either side of the spinous processes of the thoracic vertebræ is converted into a broad groove (vertebral groove), the floor of which is in part formed by the ribs as far as their angles. The grooves so formed are each occupied by the fleshy mass of the erector spinæ muscle.

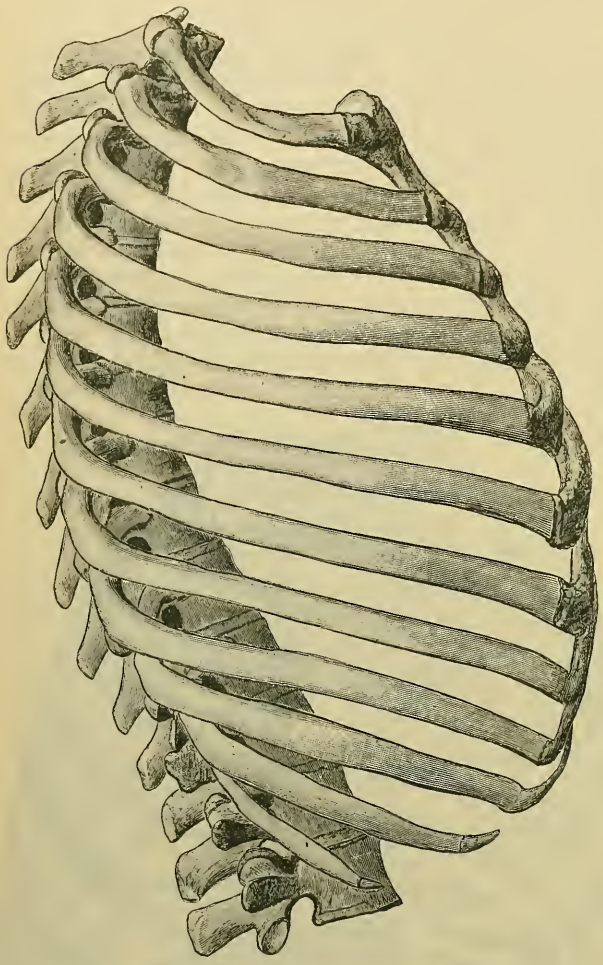


Fig. 79.—The Thorax as seen from the Right Side.

The **lateral walls** are formed by the costal arches. The ribs which run obliquely from above downwards and forwards do not lie parallel to each other, but spread somewhat, so that the intervals between them (intercostal spaces) are wider in front than behind.

The **superior aperture** or inlet formed by the body of the first thoracic vertebra behind, the arches of the first rib on either side, and the upper border of the manubrium sterni in front, is contracted and of reniform shape. The plane of the inlet is oblique from behind downwards and forwards, so that in expiration the upper border of the sternum lies on a level with the disc between the second and third thoracic vertebræ.

The **lower aperture**, of large size, is bounded in the middle line behind by the twelfth thoracic vertebra; passing thence the twelfth ribs slope outwards, downwards, and forwards. From these a line carried horizontally forwards from their tips touches the end of the eleventh rib, and then curving slightly upward reaches the cartilage of the tenth rib. Here it follows the confluent margins of the cartilages of the tenth, ninth, eighth, and seventh ribs, finally reaching the xiphoid cartilage, where it forms with the costal margin of the opposite side the subcostal angle, the summit of which coincides with the xiphi-sternal articulation; in expiration this joint usually lies on a level with the intervertebral disc between the ninth and tenth thoracic vertebræ, and corresponds with the surface depression familiarly known as the pit of the stomach. The inferior aperture of the thorax is occupied by the vault of the diaphragm.

In the fœtal condition the form of the thorax differs from that of the adult. It is laterally compressed—in this respect resembling the simian type. Its antero-posterior diameter is relatively greater than in the adult. At birth changes in form take place dependent on the expansion of the lungs; during subsequent growth, the further expansion of the thoracic cavity in a transverse direction is correlated with the assumption of the erect posture, and the use of the fore-limbs as prehensile organs.

Sexual Differences.—The thorax of the female is usually described as being proportionately shorter and rounder than the male. It also tends to narrowness in the lower segment. It is hardly necessary to point out that the natural form is often modified by the use of tight or ill-fitting corsets.

THE BONES OF THE SKULL (Ossa Cranii).

The term skull (cranium) is commonly employed to signify the entire skeleton of the head. This comprises the bony envelope which surrounds the brain (cranium cerebrale), and the osseous structures which support the face (cranium viscerale, ossa faciei).

In catalogues of craniological collections the terms used are as follows:—
Skull = entire skeleton of head, including the mandible.
Cranium = the skull, minus the mandible.
Calvaria = that part of the skull which remains after the bones of the face have been removed or destroyed.

The cranium cerebrale is composed of the **occipital** (os occipitale), the **sphenoid** (os sphenoidale), the **ethmoid** (os ethmoidale), and the **frontal** (os frontale), the two **parietals** (ossa parietalia), and the two **temporals** (ossa temporalia)—eight bones in all.

The bones of the face (cranium viscerale, ossa faciei) include the following:—Two single, viz. the **vomer** (vomer), and the **inferior maxilla** or **mandible** (mandibula), and twelve bones, arranged in pairs, viz. the **superior maxillary** (maxillæ), **malar** (ossa zygomatica), **palate** (ossa palatina), together with the **lachrymal** (ossa lacrymalia), **nasal** (ossa nasalia), and **inferior turbinated** (conchæ inferiores)—fourteen bones in all.

According to the scheme of international nomenclature, the inferior turbinals, the lachrymals, the nasals, and the vomer are included under the cranium cerebrale, and not with the cranium viscerale.

The hyoid bone is usually described along with the skull. If, in addition, the bones of the middle ear, three on each side (malleus, incus, and stapes), be included, the skeleton of the head consists of twenty-nine bones.

The separate bones will first be described, and then the skull will be considered as a whole and in section.

THE SEPARATE BONES OF THE SKULL.

The Frontal Bone.

The **frontal bone** (os frontale), situated in the fore part of the cranium, is a single bone formed by the fusion in early life of two symmetrical halves. It consists of a **frontal part**, which corresponds to the region of the forehead; an **orbital part**, which enters in the structure of the roof of the orbits; and a **nasal part**, which assists in forming the roof of the nasal fossæ.

The **frontal part** (pars frontalis) is the shell-like portion of the bone which rises upwards above the orbital arches. Its external surface is rounded from side to side and from above downwards. This convexity is most pronounced about 1¼ inches above the orbital margins on either side of the middle line, constituting what are known as the **frontal eminences** (tubera frontalia). These mark the original sites of the centres from which the bone ossifies. The lower margin of this part is formed on either side of the middle line by the curved **orbital margins** (margines supraorbitales), the outer and inner extremities of which constitute the **external** and **internal angular processes** respectively. The latter descend to a lower level than the former, and articulate with the lachrymal

bones, being separated from each other by a rough articulate surface—the **nasal notch** for the nasal and superior maxillary bones. The curve of the orbital margin varies in different individuals and races; towards its inner third it is crossed by a groove, not unfrequently converted into a foramen—the **supraorbital notch** or **foramen** (incisura sive foramen supraorbitalis). Through this there pass the supraorbital nerve and artery. Above the supraorbital margin the character of the bone displays marked differences in the two sexes: in the male, above the interval between the two internal angular processes, there is usually a well-marked prominence, called the **glabella**, from this the fulness extends outwards above the orbital margin, varying in degree and extent, and forming the elevations known as the **supraorbital** or **superciliary ridges** (arcus superciliares). The prominence of these naturally reacts on the character of the supraorbital margins, which are thicker and more rounded in the male than in the female. Passing upwards over the glabella, the remains of the suture which originally separated the two halves of the frontal bone can usually be seen; above this point all trace of the suture is generally obliterated.

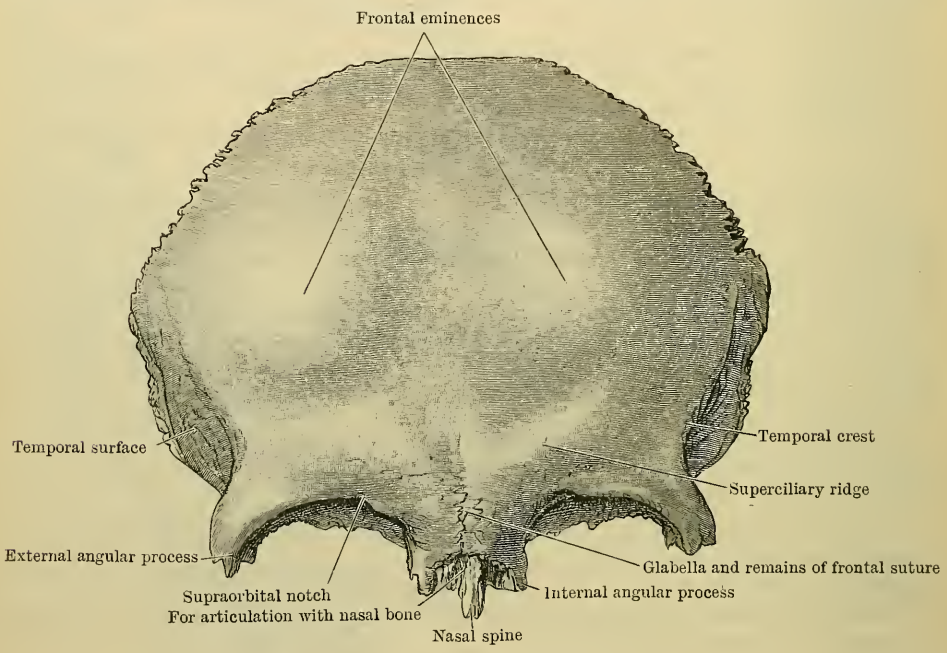


Fig. 80.—Frontal Bone (Anterior View).

Extending upwards from the external angular process is a well-marked ridge, which curves upwards and slightly inwards, then turning backwards it arches across the lateral aspect of the bone. This is the **temporal ridge** or **crest** (linea temporalis), which serves to separate the anterior surface of the frontal portion of the bone from its temporal aspect. The latter (facies temporalis) forms the floor of the upper and anterior part of the temporal fossa, and serves for the attachment of the temporal muscle.

The **orbital part** of the bone (pars orbitalis) consists of two transversely-curved plates, each having the form of a sextant; their inner edges, which are cellular, lie parallel to each other, and are separated in their posterior half by the **ethmoidal notch** (incisura ethmoidalis), in which the ethmoid bone is lodged. The edges of the notch on either side are grooved in front and behind by the **anterior** and **posterior ethmoidal foramina**, which are completed when the ethmoid is *in situ*. The anterior transmits the internal branch of the nasal nerve and the anterior ethmoidal vessels; the posterior, the posterior ethmoidal vessels. In front of the ethmoidal notch is the nasal notch, from the centre of which the **nasal process** projects downwards and forwards to terminate in the **nasal spine** (spina nasalis), which lies between, and articulates with the nasal bones and perpendicular plate of the ethmoid. On either side

of the root of this process the bone is grooved obliquely from above downwards and forwards, and enters into the formation of the narrow roof (pars nasalis) of the nasal fossæ. Anteriorly the nasal notch is limited by a rough U-shaped articular surface, the median part of which articulates with the nasal bones, whilst on either side the nasal processes of the superior maxillæ are united with it. Behind this, amid the broken cells, the passages leading into the frontal sinuses are readily distinguished, and here the inner edges of the orbital plates articulate with the lachrymal bones.

The **orbital plate** is thin and brittle. In front it is bounded by the superior orbital margin, just within which, midway between the internal angular process and the supraorbital notch there is a small shallow depression (fovea trochlearis), often displaying a spicule of bone arising from its edge (spina trochlearis), which affords attachment to the pulley of the superior oblique muscle of the eyeball. Externally the orbital plate is overhung by the orbital margin and the external angular process, and in the hollow so produced (fossa glandulæ lachrymalis) the lachrymal gland is lodged. The extremity of the **external angular process** (processus zygomaticus) articulates with the frontal process of the malar bone. Behind

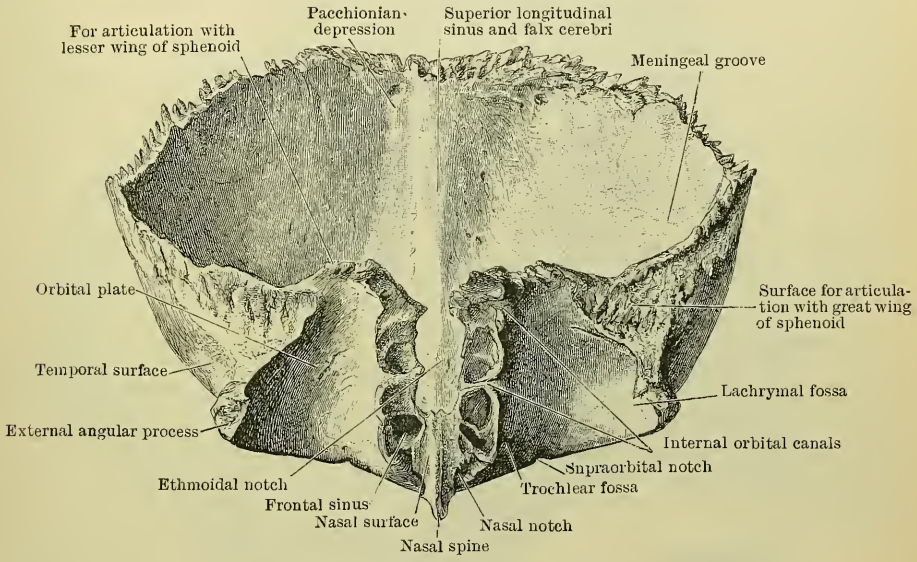


Fig. 81.—Frontal Bone as seen from Below.

this the irregular edge of the orbital plate is united with the great wing of the sphenoid by a triangular area, which also extends on to the inferior aspect of the temporal surface of the frontal bone. The apex of the orbital plate, for the space of about half an inch, articulates with the lesser wing of the sphenoid.

The *cerebral surface* of the bone forms a fossa in which lie the fore and under parts of the frontal lobes of the cerebrum, the convolutions of which impress their form on the inner aspect of the bone. Here, too, on either side of the middle line, may be seen depressions for the lodgment of Pacchionian bodies. Descending from the centre of the upper margin of the bone is a vertical groove, the **frontal sulcus**; narrowing below, this ends in a ridge—the **frontal crest**—which nearly reached the fore part of the ethmoidal notch, where it terminates in a small orifice, the foramen cæcum, placed usually in the suture between the fore part of the ethmois and the frontal. This foramen may, or may not, transmit a small vein from the nose to the commencement of the superior longitudinal sinus. This sinus, which is interposed between the layers of the falx cerebri, is at first attached to the frontal crest, but subsequently occupies the frontal sulcus. Deeply concave from side to side and from above downwards, the lateral aspects of the fossa are seen to be traversed by small grooves for the anterior branches of the middle meningeal arteries. Below, the orbital plates bulge into the floor of the fossa, so that the

ethmoidal notch appears recessed between them. On either side of the notch faint grooves for the meningeal branches of the ethmoidal vessels may be seen. The circumference of the fossa is formed by the serrated edges of the bone which articulate with the parietals above, and on either side below with the great and lesser wings of the sphenoid.

Connexions.—The frontal articulates with twelve bones, viz. posteriorly with the parietals and sphenoid; externally with the malars; inferiorly and internally with the nasals, superior maxillæ, lachrymals, and ethmoid.

Architecture.—The frontal bone is composed, like the other bones of the cranial vault, of two layers of compact tissue, enclosing between them a layer of spongy cancellous texture—the diploe. In certain definite situations, owing to the absorption of this intermediate layer, the bone is hollow, forming the **frontal air sinuses**. The position and extent of these is to some extent indicated by the degree of projection of the superciliary ridges, though this must not be taken as an absolutely reliable guide, for cases are recorded where the ridges were low and the sinuses large, and *vice versa*. Of much surgical importance, these air-spaces only attain their full development after the age of puberty, being of larger size in the male than in the female, a circumstance which accounts for the more vertical appearance of the forehead in woman as contrasted with man. Usually two in number, they are placed one on either side of the middle line, and communicate by means of the infundibulum with the nasal fossa of the same side. It is exceptional to find the sinuses of opposite sides in communication with each other, as they are generally separated by a complete partition which, however, is occasionally much deflected to one or other side. Logan Turner ("On the Illumination of the Air Sinuses of the Skull, with some Observations upon the Surgical Anatomy of the Frontal Sinus," *Edin. Med. Jour.*, May 1898) gives the average dimensions of these sinuses as follows:—Height, 31 mm., *i.e.* from the fronto-nasal aperture upwards; breadth, 30 mm., *i.e.* from the septum horizontally outwards; depth, 17 mm., from the anterior wall at the level of fronto-nasal suture backwards along the orbital roof. Exceptionally large sinuses are sometimes met with extending backwards over the orbit so as to form a double roof to that space. There is a specimen in the Oxford collection in which the sinus is so large, and extends so far back, that the optic nerve is carried through it in a bony tube. Another point of some practical importance is that the sinuses are hardly ever symmetrical. It is rare to meet with cases of their complete absence, although sometimes the sinus on one or other side may be wanting.

The external angular process, from the arrangement of its surfaces and the density of its structure, is particularly well adapted to resist the pressure to which it is subjected when the jaws are firmly closed.

Variations.—That most frequently met with is a persistence of the suture which unites the two halves of the bone in the infantile condition: skulls displaying this peculiarity are termed **metopic**. The researches of various observers—Broca, Ranke, Gruber, Manouvrier, Anoutchine, and Papillault (*Rev. mens. de l'école d'Anthropol. de Paris*, année 6, n. 3)—point to the more frequent occurrence of this metopic suture in the higher than in the lower races of man; and Calmette asserts its greater frequence in the brachycephalic than the dolichocephalic type. Separate ossicles (Wormian bones) may occur in the region of the anterior fontanelle. The fusion of these with one or other half of the frontal explains how the metopic suture is not always in line with the sagittal suture (Stieda, *Anat. Anz.* 1897, p. 227); they occasionally persist, however, and form by their coalescence a bregmatic bone (G. Zoja, *Bull. Scientifico*, xvii. p. 76, Pavia). Turner (*Challenger Reports*, part xxix.) records an instance of direct articulation of the frontal with the orbital plate of the superior maxilla in a Bush skull, and other examples of the same anomaly, which obtains normally in the skulls of the chimpanzee and gorilla, have been observed (*Jour. Anat. and Physiol.* vol. xxiv. p. 349).

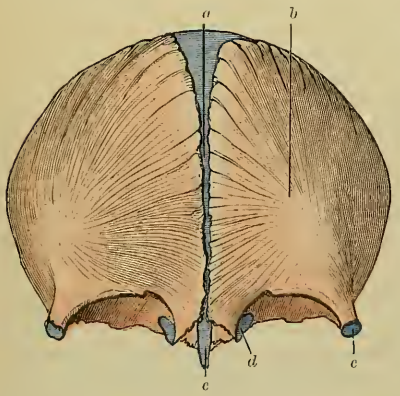


Fig. 82.—Ossification of Frontal Bone.

a, Metopic suture still open. *b*, Position of primary centre. *c*, Centre for external angular process. *d*, Centre for region of trochlea. *e*, Centres for nasal spine.

Schwalbe (1901) records the presence of small independent ossicles (supranasal bones) in the anterior part of the metopic suture. The same anatomist has also recently directed attention (*Zeit. f. Morph. und Anthr.* vol. iii. p. 93) to the existence of the metopic fontanelle, first described by Gerdy, and the occurrence of metopic ossicles (ossa interfrontalia) and canals.

Ossification.—Ossification begins in membrane from two centres, which appear about the sixth or seventh week, one on either side immediately above the orbital margin. From these the two halves of the frontal part of the bone are developed, and by extension inwards and backwards from their lower part the orbital plates are also formed. Serres, Rambaud, and Renault and v. Ihering describe the occurrence of three pairs of secondary centres somewhat later: one pair for the nasal spine on either side of the foramen cæcum; a centre on either side in

correspondence with the position of each trochlear fossa; and a centre for each external angular process. Fusion between these secondary and the primary centres is usually complete about the sixth or seventh month of fœtal life. At birth the two symmetrical halves of the bone are separated by the metopic suture, obliteration of which gradually takes place, so that about the fifth or sixth year it is more or less completely closed, traces only of the suture being left above and below. In about eight per cent of Europeans, however, the suture persists in the adult (see *ante*). At birth the supraorbital notches lie near the middle of the supraorbital arches.

Traces of the frontal sinuses may be met with about the second year, but it is only about the age of seven that they can be definitely recognised. From that time they increase in size till the age of puberty, subsequent to which time they attain their maximum development.

The Parietal Bones.

The **parietal bones** (ossa parietalia), two in number, are placed on either side of the vault of the cranium, articulating with the frontal anteriorly, the occipital

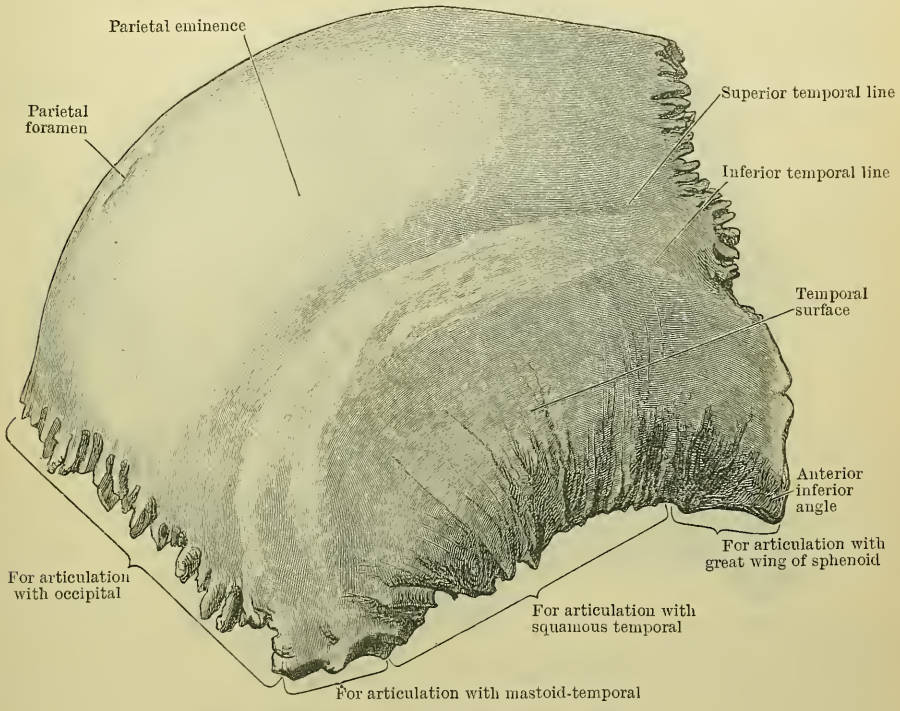


Fig. 83.—Right Parietal Bone (Outer Side).

posteriorly, and the temporals and sphenoid inferiorly. Each bone possesses an external and internal surface, four borders, and four angles.

The *external surface*, convex from above downwards and from before backwards, displays towards its centre a more or less pronounced elevation, the **parietal eminence** (tuber parietale). This marks the position of the primitive ossific centre, and not unfrequently corresponds to the point of maximum width of the head. At a variable distance from the lower border of the bone, and more or less parallel to it, two curved lines can usually be distinguished; these together constitute the **temporal crest.** The **superior temporal line** (linea temporalis superior) serves for the attachment of the temporal fascia; the **inferior temporal line** (linea temporalis inferior) defines the attachment of the temporal muscle, the extent and development of which necessarily determines the position of the crest. The surface below the crest enters into the formation of the floor of the **temporal fossa**, and is called the **planum temporale**; it also affords origin to the temporal muscle, and is often faintly marked by grooves which indicate the course of the middle temporal artery.

Above the superior temporal line the bone is covered only by the tissues of the scalp. Near its upper border, and about an inch from its posterior superior angle, is the small **parietal foramen** (foramen parietale), through which pass a small arteriole and an emissary vein.

The *inner* or *cerebral aspect* is concave from side to side and from above downwards, moulded over the surface of portions of the frontal, parietal, occipital, and temporal lobes of the cerebrum, it displays impressions corresponding to the arrangement of the convolutions of these portions of the brain. It also presents a series of well-marked grooves for the lodgment of the branches of the middle meningeal artery; these radiate from the anterior inferior angle of the bone, the best marked running upwards at some little distance behind and parallel to its anterior border. Within the upper margin are a series of depressions for Pacchionian bodies, and here also the bone is channelled so as to form a groove (sulcus sagittalis), which is completed by articulation with its fellow of the opposite side. Within

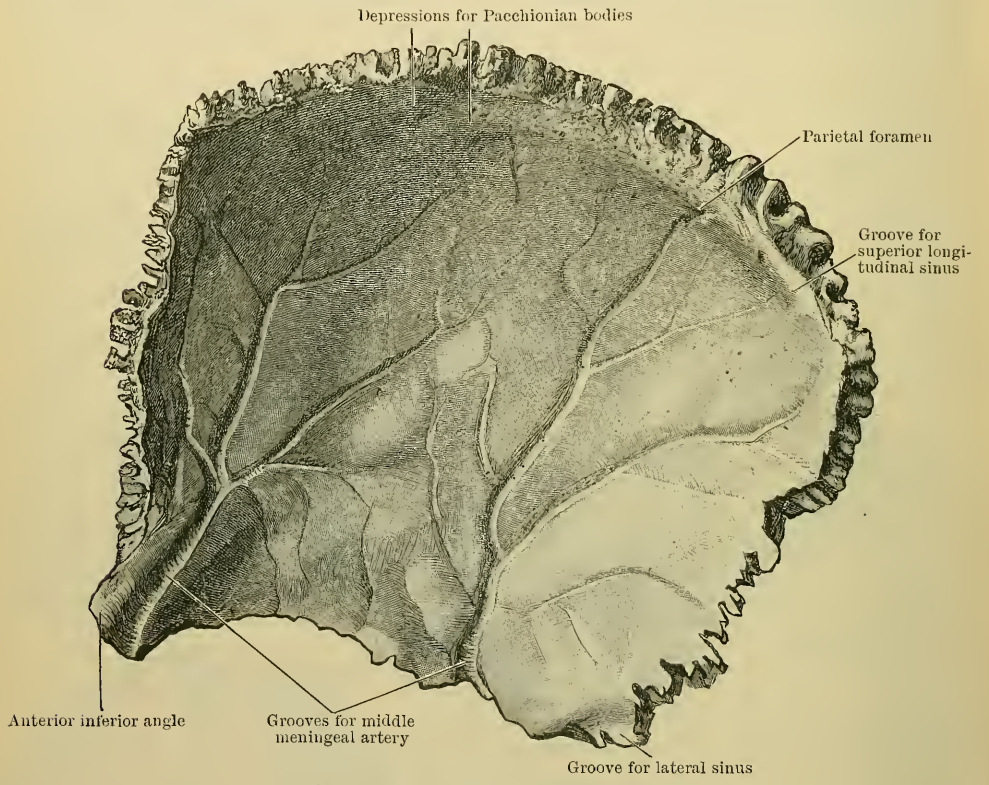


Fig. 84.—Right Parietal Bone (Inner Surface).

this groove lies the superior longitudinal venous sinus, and to its edges the falx cerebri is attached. Close to the inferior posterior angle there is also a curved groove, the lateral sulcus, in which the lateral venous sinus is lodged.

The *anterior, superior,* and *posterior borders* are deeply serrated. The anterior articulates with the frontal bone, and constitutes the coronal suture; the posterior is united with the occipital bone, and forms the lambdoid suture. The superior border articulates with its fellow of the opposite side by means of the sagittal suture; in the interval between the two parietal foramina this suture is usually simple in its outline. The *anterior superior angle* (angulus frontalis) is almost rectangular, and corresponds to the site of the anterior fontanelle. The *posterior superior angle* (angulus occipitalis), usually more or less rounded, corresponds in position to the posterior fontanelle. The *inferior border* is curved, and shorter than the others; it lies between the anterior and posterior inferior angles. Sharp and bevelled at the expense of its outer table, it displays a fluted arrangement, and articulates with the squamous part of the temporal bone. The *anterior inferior angle* (angulus

sphenoidalis), pointed and prominent, articulates with the great wing of the sphenoid. It is wedged into the angle formed by the union of that bone with the frontal, and is bevelled at the expense of its inner table anteriorly, whilst inferiorly it is thinned at the expense of its outer table. The *posterior inferior angle* (angulus mastoideus) is a truncated angle lying between the inferior and posterior borders. It is deeply serrated, and articulates with the mastoid process of the temporal bone. Not unfrequently there is a channel in this suture which transmits an emissary vein.

Connexions.—The parietal bone articulates with its fellow, with the frontal, occipital, mastoid and squamous temporal, and with the sphenoid. Occasionally the inferior angle may not reach the great wing of the sphenoid, being separated from it by the articulation of the squamous temporal with the frontal (see also p. 119).

Architecture.—Thin towards its lower part, where it enters into the formation of the temporal fossa, it is thickest along the superior border and in the neighbourhood of the posterior superior angle.

Variations.—A number of cases have been recorded in which the parietal is divided into an upper and lower part by an antero-posterior suture parallel to the sagittal suture. Coraini (*Atti. d. XI. Congr. Med. Internaz. Roma*, 1894, vol. v.) records a case in which the parietal was incompletely divided into an anterior and posterior part by a vertical suture. The parietal foramina vary greatly in size, and to some extent in position. They are sometimes absent on one or other side, or both. They correspond in position to the sagittal fontanelle. Sometimes the ossification of this fontanelle is incomplete and a small transverse fissure remains. The parietal foramen represents the patent external extremity of this fissure after its edges have coalesced. Occasionally in the region of the anterior fontanelle an ossicle of variable size may be met with. This is the so-called prae-interparietal bone. According to its fusion with adjacent bones it may disturb the direction of the sagittal suture.

Ossification.—Ossification takes place in membrane by the deposition of earthy matter, the centre for which, most probably formed by the coalescence of two nuclei, appears over the parietal eminence about the sixth or seventh week of fœtal life; from this it spreads in a radial manner towards the edges of the bone, where, however, the membranous condition still for some time persists constituting the fontanelles. These correspond in position to the angles of the bone. Ossification is also somewhat delayed in the region of the parietal foramina, constituting what is known as the sagittal fontanelle, a membranous interval which is not unfrequently apparent even at birth.

The Occipital Bone.

The **occipital bone** (os occipitale), placed at the back and lower part of the cranium, consists of three parts, arranged around a large oval hole, called the occipital foramen or foramen magnum. The expanded curved plate behind the foramen is the **tabular** or **squamous part**. The thick rod-like portion in front of the foramen is the **basilar process**. On either side the foramen is bounded by the **lateral** or **condylic portions**.

The **tabular** or **squamous part** (squama occipitalis) in shape somewhat resembles a Gothic arch, and is curved from side to side and from above downwards. It forms inferiorly a small portion of the middle of the posterior boundary of the foramen magnum, and unites on either side of that with the lateral parts of the bone. About the centre of the *external surface* of the squama there is a prominence—the **external occipital protuberance** (protuberantia occipitalis externa), which varies considerably in its distinctness and projection, and serves for the attachment of the ligamentum nuchæ. From the protuberance on either side two lines curve out towards the external angles of the bone. These are known respectively as the **highest** and **superior curved lines** (linea nuchæ suprema and linea nuchæ superior). To the upper of these the epicranial aponeurosis is attached, whilst the lower serves for the origin of the trapezius and occipitalis muscles and the insertion of the sterno-mastoid and splenius capitis muscles. The two lines together serve to divide the external surface of the tabular part into an upper or **occipital portion** (planum occipitale), covered by the hairy scalp and a lower or **nuchal part** (planum nuchale) serving for the attachment of the fleshy muscles of the back of the neck. As a rule the occipital part bulges backwards beyond the external occipital protuberance; exceptionally, however, the latter process is the most outstanding part of the bone.

The **nuchal plane**, irregular and rough, is divided into two lateral halves by a median ridge—the **external occipital crest** (linea nuchæ mediana), which stretches

from the external occipital protuberance above to the posterior border of the foramen magnum below. Crossing the nuchal plane transversely, about its middle, is the **inferior curved line** (linea nuchæ inferior), which passes outwards and forwards on either side towards the lateral margins of the bone. The areas thus marked out serve for the attachment of the complexus, obliquus superior, and rectus capitis posticus major and minor muscles.

The *internal surface* of the squama, concave from side to side and from above downwards, is subdivided into four fossæ by a crucial arrangement of ridges and grooves. The upper pair of fossæ lodges the occipital lobes of the cerebrum, the lower pair the lobes of the cerebellum. Near the centre of this aspect of the bone is the **internal occipital protuberance** (protuberantia occipitalis interna), an irregular elevation, the sides of which are variously channelled according to the disposition of the grooves. Leading from this to the hinder margin of the foramen magnum

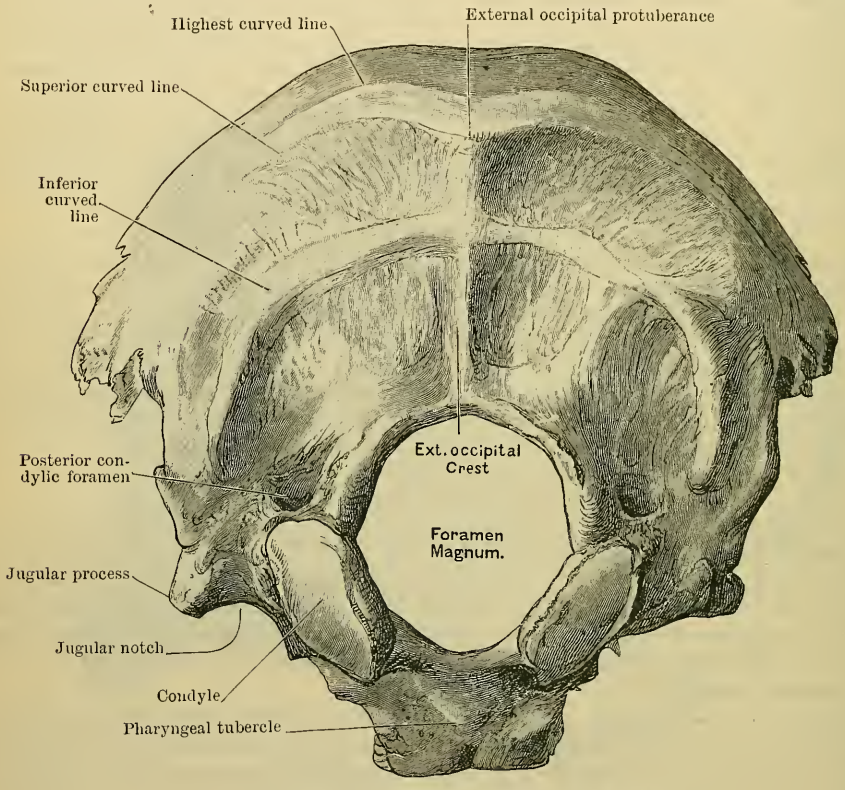


Fig. 85.—Occipital Bone as seen from Below.

is a sharp and well-defined ridge, the **internal occipital crest** (crista occipitalis interna), which serves for the attachment of the falx cerebelli, a process of dura mater which separates the two cerebellar hemispheres. Passing upwards from the internal occipital protuberance there is usually a well-marked ridge, to one or other side of which, more frequently the right (with the bone in the normal position and viewed from behind), there is a well-defined groove, the **sulcus sagittalis**, the outer lip of which is generally less prominent. Placed in this groove is the superior longitudinal venous sinus, and attached to the lips is the falx cerebri. At right angles to the foregoing, and at the level of the internal occipital protuberance, with which they become confluent, are two transverse grooves, the sulci transversi. These grooves, which have more or less prominent edges, lie between the upper and lower pairs of fossæ, and serve for the attachment of the tentorium cerebelli as well as the lodgment of the lateral blood-sinuses. Commonly the right lateral groove is confluent with the groove to the right side of the median ridge, but exceptions to this rule are not infrequent. The angle formed by the union of the venous sinuses

lodged in these grooves constitutes the torcular Herophili, which may accordingly be placed to one or other side of the internal occipital protuberance, more frequently the right; in some cases, however, it may occupy a central position.

The *superior angle*, more or less sharp and pointed, is wedged in between the two parietal bones, its position corresponding to the site of the posterior fontanelle. The *lateral angle* articulates on either side with the posterior extremity of the mastoid portion of the temporal bone. The *superior borders*, much serrated, articulate with the parietal bones forming the **lambdoid suture**; and the *lateral edges*, extending from the external angles to the jugular process inferiorly, are connected with the inner sides of the mastoid portions of the temporals.

The **lateral** or **condylic parts** of the occipital bone (partes laterales) are placed

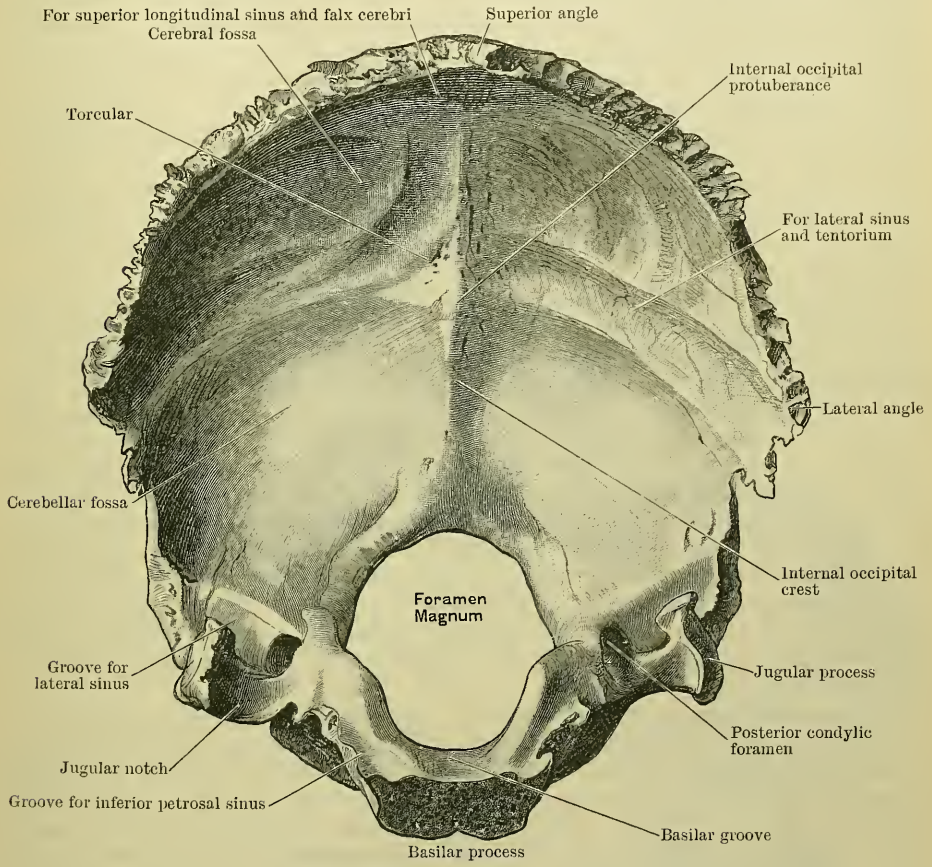


FIG. 86.—OCCIPITAL BONE (Inner Surface).

on either side of the foramen magnum; on their under surface they bear the condyles (condyli occipitales) by means of which the skull articulates with the atlas vertebra. Of elongated oval form, the condyles are so disposed that their anterior extremities, in line with the anterior margin of the foramen magnum, lie closer together than their posterior ends, which extend as far back as the middle of the external borders of the foramen. Convex from before backwards, they are skewed so that their surfaces, which are nearly plane from side to side, are directed slightly outwards. Each is supported on a boss of bone, pierced by the **anterior condylic foramen** (canalis hypoglossi), which opens obliquely from within outwards and forwards on the floor of a fossa called the **anterior condylic fossa**, situated just external to the fore part of the condyle. The foramen transmits the hypoglossal or XII. cranial nerve, together with a meningeal branch of the ascending pharyngeal artery and its companion veins. Behind the condyle is placed the **posterior condylic fossa**, in the floor of which the **posterior condylic foramen** frequently opens. Through

this a vein passes which joins the lateral sinus. The edge of the foramen magnum immediately behind the condyle is often grooved for the passage of the vertebral artery around it. Jutting out from the posterior half of the condyle is a stout bar of bone, serially homologous with the vertebral transverse process—this is the **jugular process** (processus jugularis); deeply notched in front, its anterior border is free and rounded, and forms the posterior boundary of the jugular foramen. Curving outwards from this margin, in line with the anterior condylic foramen, there is often a small pointed projection, the **processus intra-jugulare**, which serves to divide the jugular foramen into two compartments. Externally the jugular process articulates by means of a synchondrosis with the jugular surface of the petrous part of the temporal bone. Its posterior border is confluent with the lower and lateral portion of the occipital squama, and its under surface is rough and tubercular for the attachment of the rectus capitis lateralis muscle. The *superior aspect* of the lateral part displays on either side of the foramen magnum an elevated surface of oval form, the **tuberculum jugulare**; this corresponds to the part of the bone which bridges over the canal for the hypoglossal nerve. Its upper surface in many instances displays an oblique groove running across it; in this are lodged the glosso-pharyngeal, vagus, and accessory nerves. The jugular process is deeply grooved superiorly for the lower part of the lateral blood sinus, which here turns round the anterior free edge of the process into the jugular foramen. Joining this, close to its inner edge, is the opening of the posterior condylic foramen when that canal exists.

The **basilar part** of the occipital bone (pars basilaris) extends forwards and upwards from the foramen magnum. Its anterior extremity is usually sawn across, as, after adult life, it is necessary to sever it in this way from the sphenoid, the cartilage uniting the two bones having by that time become completely ossified. Broad and thin behind, it narrows laterally and thickens vertically in front, where on section it displays a quadrilateral form. Projecting from its under surface some little distance in front of the foramen magnum is the **pharyngeal tubercle** (tuberculum pharyngeum) to which the fibrous raphe of the pharynx is attached; on either side of this the rectus capitis anticus major and minor muscles are inserted. The *upper surface* forms a broad and shallow groove which slopes upwards and forwards from the thin anterior margin of the foramen magnum; in this rests the medulla oblongata. On either side its lateral edges are faintly grooved for the inferior petrosal venous sinuses, below which the lateral aspect of the bone is rough for the cartilage which unites it to the sides and apex of the petrous part of the temporal bone.

The **foramen magnum**, of oval shape, so disposed that its long axis lies in the sagittal plane, is of variable size and form. The plane of its outlet differs somewhat in individual skulls; in most instances it is directed downwards and slightly forwards. In front the condyles encroach upon it, and narrow to some extent its transverse diameter. To its margins are attached the ligaments which unite it with the atlas and axis. Through it pass the lower part of the medulla oblongata where it becomes continuous with the spinal cord, the two vertebral arteries, the spinal accessory nerves, and the blood-vessels of the meninges of the upper part of the cord.

Connexions.—The occipital bone articulates with the two parietals in front and above, with the sphenoid in front and below, with the two temporals on either side, and with the atlas vertebra by means of its condyles.

Architecture.—The squamous part displays thickenings in the position of the various ridges and crests, the stoutest part corresponding to the internal and external occipital protuberances, though it should be noted that the two protuberances do not necessarily coincide, the internal being, as a rule, placed at a higher level than the external. If the bone be held up to the light it will be at once apparent that it is much thinner where it forms the floor of the inferior fossæ than in the upper part. The basilar portion consists of a spongy core surrounded by a more compact outer envelope, thickest on its lower surface. In the condyles the spongy tissue is arranged radially to their convex articular surfaces, the hypoglossal canal being surrounded by particularly dense and compact bone.

Variations.—The most striking of the many variations to which this bone is subject is the separation of the upper part of the occipital squama to form an independent bone—the interparietal bone, called also, from the frequency of its occurrence in Peruvian skulls, the os Incæ

As will be seen below (see Ossification), the occurrence of this anomaly is explained developmentally. In place of forming a single bone the interparietal is occasionally met with in two symmetrical halves, and instances have been recorded of its occurrence in three or even four pieces. In the latter cases the two anterior parts form the pre-interparietals. Instances are recorded of the presence of a separate epiphysis between the basi-occipital and the sphenoid, the os basioticum (Albrecht) or the os præ-basi-occipital. The articular surface of the condyles is sometimes divided into an anterior and posterior part. The so-called third occipital condyle is an outstanding process rising from the anterior border of the foramen magnum, the extremity of which articulates with the odontoid process of the axis. Guerri has recorded a case, in which in a fœtal skull, there were two outstanding tubercles in the position of the third occipital condyle, independent of the basi-occipital portions of the condyles (*Anat. Anz.* vol. xix. p. 42). This appears to confirm the view of Macalister that there are two different structures included under this name—one a mesial ossification in the sheath of the notochord, and the second, a lateral, usually paired process, caused by the deficiency of the mesial part of the hypochordal element of the hindmost occipital vertebra, with thickenings of the lateral parts of the arch. Springing from the under surface of the extremity of the jugular process, a rough or smooth elevated surface, or else a projecting process, the extremity of which may articulate with the transverse process of the atlas, is sometimes met with. This is the paroccipital or paramastoid process. Numerous instances of fusion of the atlas with the occipital bone have been recorded. Many are, no doubt, pathological in their origin; others are associated with errors in development. Interesting anomalies are these in which there is evidence of the intercalation of a new vertebral element between the atlas and occipital, constituting what is termed a proatlas.

Ossification.—The major part of the bone ossifies in cartilage, the upper part of the squama (interparietal), alone developing in membrane. The **basilar part** begins to ossify about the sixth week of fœtal life by the appearance of two centres, one in front of the other; the anterior, according to Albrecht, constitutes the basiotic, the posterior the basi-occipital. These two centres—which there is some reason to believe—may themselves be formed by the fusion of pairs placed laterally, rapidly unite, so that the occurrence of one centre alone is frequently described. From this the fore part of the margin of the foramen magnum is formed, together with a portion of the anterior end of the occipital condyle on either side. It helps also to close up the front of the anterior condylic canal. Union with the condylic parts is complete about the fourth or fifth year. Ankylosis between the basi-occipital and the sphenoid takes place about the twenty-fifth year.

The **lateral, condylic,** or **exoccipital parts** begin to ossify from a single centre about the end of the second month of fœtal life. The notch for the hypoglossal canal appears about the third month. From this centre is formed the posterior three-fourths of the occipital condyle. The exoccipital is usually completely fused with the squama by the third year or earlier.

As already noted, the squama consists of two parts—the one above the occipital crest, the other below it; the former develops in membrane, the latter in cartilage. In a three-months' fœtus this difference is very characteristic. The cartilaginous part (supra-occipital) begins to ossify from two centres about the sixth or seventh week, which rapidly join to form an elongated strip placed transversely in the region of the occipital protuberance. The centres for the upper part (interparietal) appear later. According to Maggi (*Arch. Ital. Biol.* tome 26, fas. 2, p. 301), they are four in number, of which two placed on either side of the middle line appear about the second month. The other pair, placed laterally, are seen about the third month; fusion between these takes place early, but their disposition and arrangement explain the anomalies to which this part of the bone is subject. The mesial pair may persist as separate ossicles, or fuse to form the pre-interparietals, whilst the lateral pair may remain independent of the supra-occipital as a single or double interparietal bone. Union between the supra-occipital and the interparietal elements occurs about the third or fourth month; but evidence of their separation is frequently

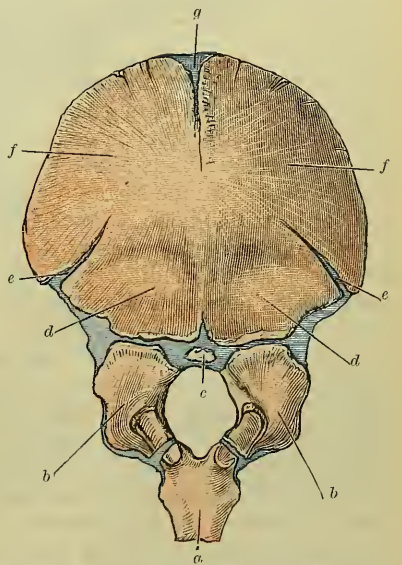


Fig. 87.—Ossification of Occipital Bone.

a, Basilar centre; *b*, Exoccipital; *c*, Ossicle of Kerkring; *d*, Supra-occipital (from cartilage); *e*, Fissure between supra-occipital and interparietal; *f*, Interparietal (from membrane); *g*, Fissure between interparietals.

met with even in the adult by the persistence of a transverse suture running inwards from each external angle of the squama, or, as above mentioned, there may be an os Incæ. The supra-occipital forms a small part of the middle of the hinder border of the foramen magnum, though here a small independent centre, known as the ossicle of Kerkring, is occasionally met with. Other independent centres are sometimes seen between the supra-occipital and the exoccipitals.

At birth the occipital consists of four parts—the interparietal and supra-occipital combined, the basi-occipital, and the exoccipitals—one on either side.

The Temporal Bones.

The **temporal bone** (os temporale) lies about the centre of the lower half of either side of the skull, and enters largely into the formation of the cranial base. It is placed between the occipital behind, the parietal above, the sphenoid in front, and the occipital and sphenoid internally and below. At birth it consists of three parts—an upper and outer part, the **squamous** or **squamo-zygomatic portion**; an inner and posterior portion, the **petro-mastoid**, which contains the parts specially associated with the sense of hearing, together with the organ associated with equilibration; and an under or **tympanic part**, from which the floor and anterior wall of the external auditory meatus is formed.

The **squamous part** (pars squamosa) consists of a thin shell-like plate of bone placed vertically, having an inner (cerebral) and an outer (temporal) surface and a semicircular upper border. Inferiorly, behind, and internally it is fused in early life with the petro-mastoid portion by means of the squamoso-mastoid and the petro-squamosal sutures, traces of which are often met with in the adult bone; whilst below and in front it is separated from the tympanic and petrous parts by the **Glaserian fissure**. Its *external surface*, smooth and slightly convex, enters into the formation of the floor of the temporal fossa, and affords attachment to the temporal muscle. Near its hinder part it is crossed by one or more ascending grooves for the branches of the middle temporal artery. In front and below there springs from it the **zygomatic process** (processus zygomaticus). This arises by a broad attachment, the surfaces of which are inferior and superior; curving outwards and forwards, it then becomes twisted and narrow so that its sides are turned inwards and outwards and its edges directed upwards and downwards. Anteriorly it ends in an oblique serrated extremity which articulates with the zygomatic process of the malar bone. Posteriorly the edges of the zygomatic process separate and are termed its roots. The upper edge, which becomes the **posterior root**, sweeps back over the external auditory meatus, and is confluent with a ridge, the **supra-mastoid crest**, which curves backwards and slightly upwards, and serves to define the limit of the temporal fossa posteriorly. The inferior edge turns inwards and constitutes the **anterior root**; the under surface of this forms a transversely-disposed rounded ridge, the **articular eminence** (tuberculum articulare), behind which there is a deep hollow, the **glenoid fossa** (fossa mandibularis), limited posteriorly by the tympanic plate, and crossed at its deepest part by an oblique fissure, the **Glaserian fissure** (fissura petro-tympanica). This cleft, which is closed externally, transmits about its middle the tympanic branches of the internal maxillary artery, and lodges the slender process of the malleus. At its inner end the lips of this fissure are frequently separated by a thin scale of bone, a downgrowth from the tegmen tympani of the petrous part, which here separates the tympanic from the squamous elements, forming in its descent the major part of the outer wall of the osseous Eustachian canal, which lies immediately internal to it. Between this scale of bone and the posterior edge of the fissure there is a small canal (**canal of Huguier**), which transmits the chorda tympani nerve. The part of the glenoid fossa in front of the fissure articulates with the condyle of the inferior maxilla, through the medium of the interarticular cartilage, which is here interposed and rests as well on the tuberculum articulare. Posteriorly the part of the fossa behind the fissure is non-articular and lodges a portion of the parotid gland. At the angle formed by the divergence of the two roots of the zygoma, in correspondence with the outer part of the articular eminence, there is a rounded **tubercle**; to this are attached the

fibres of the external lateral ligament of the temporo-mandibular joint. In front of the inner end of the articular eminence there is a small triangular surface, limited in front by the edge of the anterior root, and internally by a thick serrated margin which articulates with the outer side of the great wing of the sphenoid; this area forms part of the roof of the zygomatic fossa. Just anterior to the external auditory meatus and projecting downwards from the under surface of the posterior root there is a conical process, called the **post-glenoid tubercle**, which forms a prominent anterior lip to the external extremity of the Glaserian fissure; it is the representative in man of a process which occurs in some mammals and prevents the backward displacement of the lower jaw. By some anatomists it is referred to as the **middle root** of the zygoma.

The **zygomatic process** by its lower margin and inner surface gives origin to the masseter muscle, whilst attached to its upper edge are the layers of the temporal fascia. Behind the external auditory meatus, and below the supramastoid crest, the

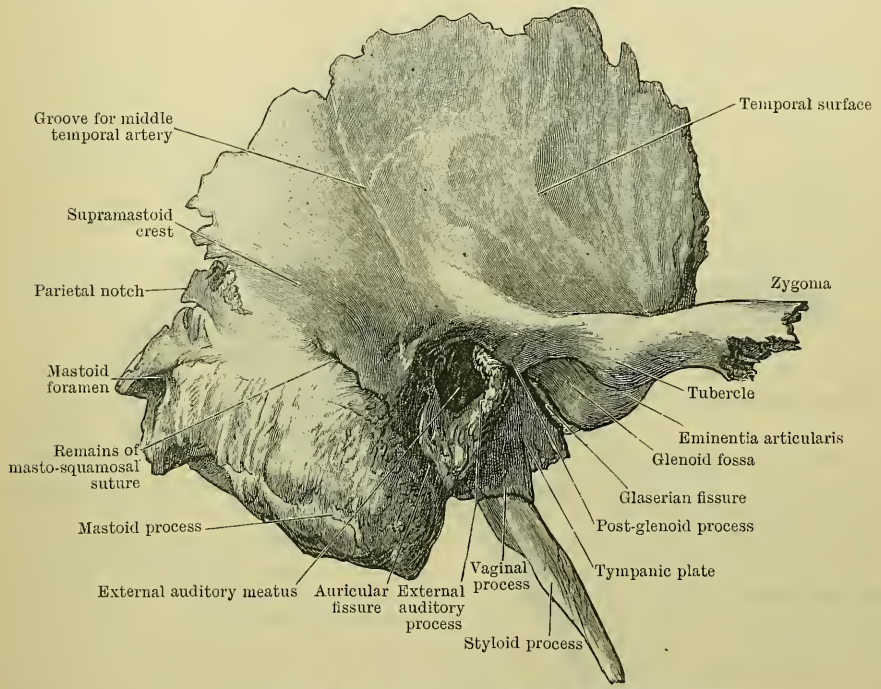


FIG. 88.—RIGHT TEMPORAL BONE AS SEEN FROM THE OUTER SIDE.

squamous element extends downwards as a pointed process, which assists in forming the roof and posterior wall of the external auditory meatus, where it unites inferiorly with the tympanic plate. In the adult this process is occasionally sharply defined posteriorly by an oblique irregular fissure, the remains of the masto-squamosal suture.

Professor Macewen has pointed out that this suture frequently remains open till puberty and occasionally after, and may be of importance as a channel along which infective processes may extend.

The *inner surface* of the squamous part, less extensive than the outer aspect owing to the bevelling of the superior border, is marked by the impression of the convolutions of the temporal lobe of the cerebrum, and is limited below by the petro-squamosal suture, the remains of which can frequently be seen. It is crossed in front by an ascending groove for the middle meningeal artery, branches from which course backwards over the bone in grooves more or less parallel to its upper border.

The *superior border* of the squamous part is curved, sharp, and scale-like, being bevelled at the expense of its inner table, except in front, where the margin is thick

and stout. Here it articulates with the great wing of the sphenoid, its union with that bone extending to near the fore part of the summit of the curve, behind which it is united to the parietal overlapping the lower border of that bone; posteriorly the free margin of the squamous part ends at an angle formed between it and the mastoid process called the **incisura parietalis.**

The **tympanic part** (pars tympanica) of the temporal bone forms the anterior, lower, and part of the posterior wall of the external auditory meatus. Bounded in front and above by the Glaserian fissure, it forms the hinder wall of the non-articular part of the glenoid fossa. Fused internally with the petrous part, its lower edge, sharp and well defined internally, splits to enclose the root of the projecting **styloid process**, and is hence called the **vaginal process.** Externally it unites with the fore part of the mastoid process, and higher up with the descending process of the squamous part, from both of which it is separated by the **auricular fissure** (fissura tympano-mastoidea) through which the auricular branch of the

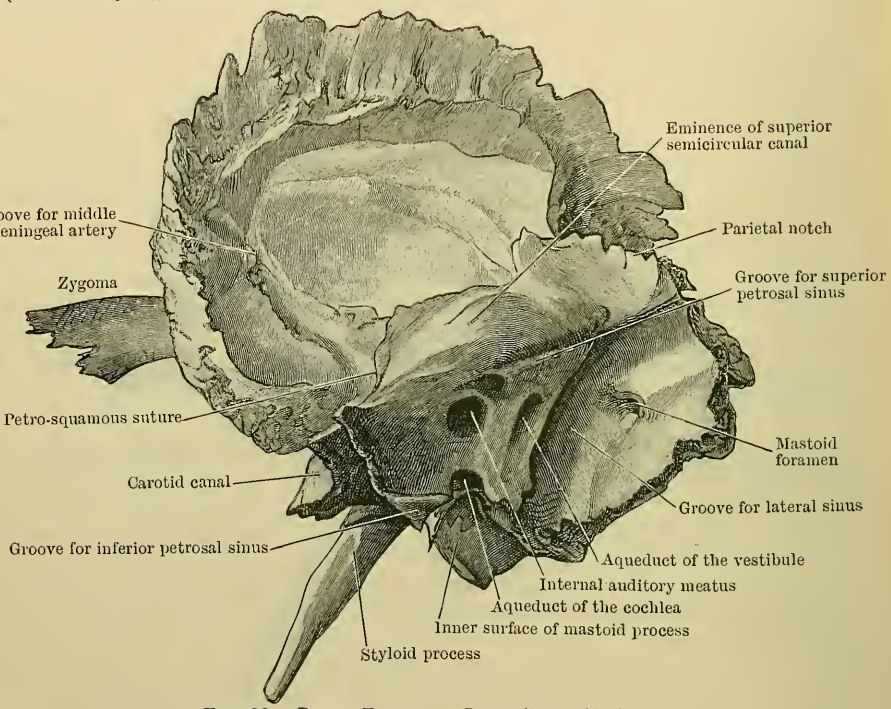


FIG. 89.—RIGHT TEMPORAL BONE (Inner Side).

vagus escapes. Its free border, which forms the anterior, lower, and part of the posterior border of the external auditory meatus, is usually somewhat thickened and rough, and serves for the attachment of the cartilaginous part of the canal.

The **external auditory meatus** (meatus acusticus externus) is directed obliquely inwards and a little forwards, and describes a slight curve, the convexity of which is directed upwards; of oval form, its long axis, close to its orifice, is nearly vertical, but, as it passes inwards, inclines somewhat forwards so as to give a twist to the canal. The depth of the canal to the attachment of the membrana tympani averages from 14 to 16 mm. The upper margin of the outer orifice overhangs considerably the lower edge, but owing to the obliquity of the inner aperture, to which the membrana tympani is attached, the upper wall of the osseous canal only exceeds the length of the lower wall by one or two millimetres.

The **petro-mastoid part** (pars petrosa et mastoidea) of the temporal bone, of pyramidal form, is fused to the inner aspect of the tympanic and squamosal portions, extending behind them, however, to form the well-marked and prominent **mastoid process**, which lies posterior to the external auditory meatus. This process (pars mastoidea) forms a nipple-like projection, the size of which differs considerably in different individuals. Usually larger in the male than in the female, its rough

outer surface and lower border serve for the insertions of the sterno-mastoid, splenius capitis, and trachelo-mastoid muscles. Within and below its pointed extremity there is a deep groove (incisura mastoidea), usually well marked, which gives origin to the posterior belly of the digastric muscle; whilst lying to the inner side of this, and separated from it by a more or less well-defined rough ridge, there can oftentimes be seen a narrow, shallow furrow, which indicates the course of the occipital artery. The **inner surface** of the mastoid portion forms, in part, the lateral wall of the posterior cranial fossa, in which the cerebellar lobes are lodged. Coursing across this aspect of the bone there is a broad curved groove, the convexity of which is directed forwards and lies in the angle formed by the base of the petrous part and its fusion with the mastoid portion. The depth to which the bone is here channelled varies considerably, and is important from a surgical standpoint, as herein lies the sigmoid portion of the lateral venous sinus. Anteriorly the mastoid is fused with the descending process of the squamosal above, and below, where it is united with the tympanic, it enters into the formation of the posterior wall of the external auditory meatus and the cavity of the tympanum. Above, its free margin is rough and serrated, and articulates with the posterior inferior angle of the parietal; behind and below it articulates by a jagged suture with the occipital. Traversing this suture, or near it, is the **mastoid foramen** (foramen mastoideum), which transmits a vein from the lateral sinus to the cutaneous occipital vein, together with a small branch of the occipital artery.

The **petrous part** of the petro-mastoid is of the form of an elongated three-sided pyramid. By its base it is united obliquely to the inner sides of the squamosal and tympanic parts. Its apex is directed inwards, forwards, and a little upwards. Its three surfaces are arranged as follows:—The *superior* or *anterior* looks upwards, slightly forwards, and a little outwards, and forms part of the floor of the middle cranial fossa. The *posterior* is directed backwards and inwards, and forms part of the anterior wall of the posterior cranial fossa. The *inferior* is seen on the under surface of the base of the skull, and is directed downwards. The borders are named respectively anterior, superior, and posterior.

The *anterior border* is short, and forms an acute angle with the fore part of the squamous part; within this angle is wedged the spinous part of the great wing of the sphenoid. Here, too, the osseous **Eustachian canal** (canalis musculotubarius) may be seen leading backwards and outwards from the summit of the angle to reach the fore part of the cavity of the tympanum. On looking into it, the canal is seen to be divided into two unequal parts by an osseous partition, the **cochleariform process** (septum tubæ). The upper compartment, the smaller of the two (semicanalis m. tensoris tympani), lodges the tensor tympani muscle, whilst the lower (semicanalis tubæ auditivæ) forms the osseous part of a channel (the **Eustachian tube**), which serves to conduct air from the pharynx to the tympanum.

The *posterior border* is in part articular and in part non-articular. Posteriorly and externally it corresponds to the upper margin of an area on the inferior surface with which the extremity of the jugular process of the exoccipital articulates. In front of that it is irregularly notched, and forms the free anterior edge of the jugular foramen, internal to which it has a sharp curved border, often grooved, reaching to the apex. This groove, which is completed by articulation with the outer side of the basi-occipital, lodges the inferior petrosal venus sinus.

The *superior border* is a twisted edge which is continuous with the upper margin of the groove for the lateral sinus posteriorly, and anteriorly and internally reaches the apex of the bone. Running along it there is usually a well-marked groove for the superior petrosal venous sinus, and near its inner extremity it is slightly notched for the passage of the trigeminal nerve. Along the entire length of this border the tentorium cerebelli is attached.

On the *inferior surface* of the petrous part, which is bounded in front by the anterior border internally, and the tympanic plate externally, and behind by the posterior border, the following structures are to be noted:—Springing from and ensheathed by the vaginal process is the slender and pointed **styloid process** (processus styloideus), the length of which varies much. Projecting downwards and slightly forwards and inwards, it affords attachments for the stylo-glossus,

stylo-hyoid, and stylo-pharyngeus muscles as well as the stylo-hyoid and stylo-mandibular ligaments. Just behind it, and between it and the mastoid process, is the **stylo-mastoid foramen** (foramen stylomastoideum), which lies at the anterior end of the digastric groove, and transmits the facial nerve and the stylo-mastoid artery. Immediately internal to the styloid process there is a deep, smooth, excavated hollow, the **jugular fossa** (fossa jugularis), which is converted into a foramen (jugular) by articulation with the occipital bone. Behind and external to the fossa there is a small **quadrilateral surface** of variable size, which is united to the extremity of the jugular process of the exoccipital by a synchondrosis. Inside the fossa, on its outer aspect, or placed on its external border, is the opening of a small canal (canaliculus mastoideus), which passes outwards to open into the canalis facialis, and transmits the auricular branch of the vagus (Arnold's nerve), which ultimately escapes through the auricular fissure (see *ante*). In front of the jugular fossa and separated from it by a sharp crest, and just internal to the tympanic plate, is the circular opening of the inferior orifice of the **carotid canal** (canalis caroticus). Directed at first upwards, this canal bends at a right angle and turns forwards and inwards, lying parallel to the anterior border; reaching the fore part of the apex of the bone, it opens in front by an oblique ragged orifice. Through the canal the internal carotid artery, accompanied by a plexus of sympathetic nerves, passes into the cranium. On the ridge of bone separating the jugular fossa from the carotid canal is the opening of a small canal (canaliculus tympanicus), through which the tympanic branch of the glosso-pharyngeal (nerve of Jacobson) passes to reach the tympanum. Within the orifice of the carotid canal another small opening or openings (canaliculi carotici tympanici) may be noticed which afford passage to the tympanic branches of the internal carotid artery and carotid sympathetic plexus. Occupying the interval between the jugular fossa and the carotid canal on the inner side is a V-shaped depression (fossula fenestræ cochleæ), on the floor of which and close to the posterior border is the orifice of the **aqueduct** of the **cochlea** (apertura externa aquæductus cochleæ). In the fossa is lodged the petrous ganglion of the glosso-pharyngeal nerve, and the aqueduct transmits a tubular prolongation of the dura mater, which forms a channel of communication between the perilymph of the cochlea and the subarachnoid space. A small vein also passes through it. In front of and internal to the orifice of the carotid canal the under surface of the apex of the bone corresponds to a rough quadrilateral surface which forms the floor of the carotid canal, and also serves for the attachment of the cartilaginous part of the Eustachian tube as well as the origin of the levator palati muscle; elsewhere it has attached to it the dense fibrous tissue which fills up the cleft (petro-basilar fissure) between it and the basilar process of the occipital bone.

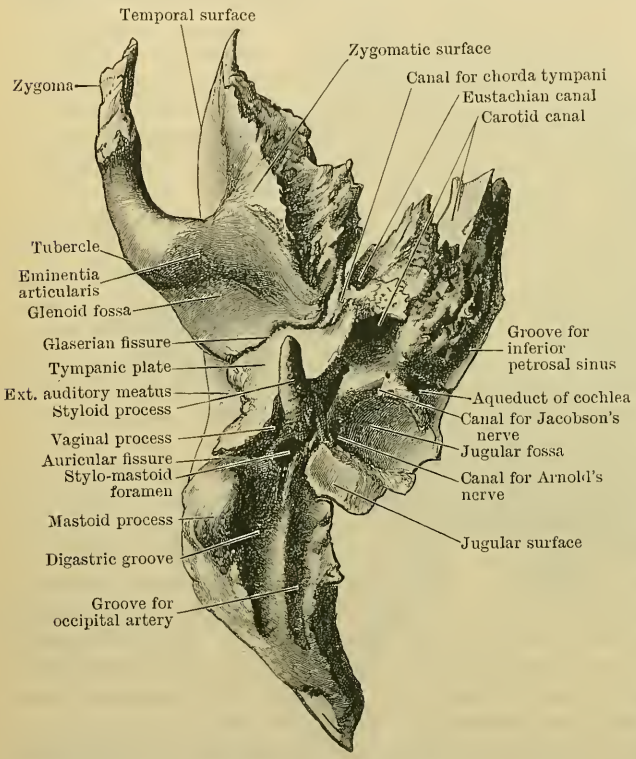


Fig. 90.—Right Temporal Bone as seen from Below.

The *superior* or *anterior surface* bears the impress of the convolutions of the under surface of the temporal lobe of the cerebrum, which rests upon it; in addition, there is a distinct but shallow depression (impressio trigemini) near the apex, corresponding to the roof of the carotid canal; in this is lodged the Gasserian ganglion on the sensory root of the V. cranial nerve. External to the middle of the upper surface, and close to its posterior border, is the elevation (eminentia arcuata), more or less pronounced, which marks the position of the superior semicircular canal here lodged within the bone. A little in front of this, and in line with the angle formed by the anterior border and the squamous part, is the slit-like opening of the **hiatus Fallopii** (hiatus canalis facialis), within the projecting lip of which two small orifices can usually be seen. These are the openings of the **aquæductus Fallopii** (canalis facialis); if a bristle be passed through the inner of the two openings it will be observed to pass into the bottom of the internal auditory meatus, if into the outer, it will pass through the aqueduct of Fallopius, and, provided the channel be clear, will appear on the under surface of the bone at the stylo-mastoid foramen. Leading forwards and inwards from the hiatus towards the anterior border is a groove; in this lies the great superficial petrosal nerve which passes out of the hiatus. A small branch of the middle meningeal artery also enters the bone here. A little external to the hiatus is another small opening (apertura superior canalis tympanici), often difficult to see; from this a groove runs forwards which channels the upper surface of the roof of the canal for the tensor tympani muscle. Through this foramen and along this groove passes the lesser superficial petrosal nerve. Behind this, and in front of the **arcuate eminence**, the bone is usually thin (as may be seen by holding it up to the light falling through the external auditory meatus), roofing in the cavity of the tympanum and forming the **tegmen tympani**. Externally the line of fusion of the petrous with the squamous part is often indicated by a faint and irregular petro-squamous fissure.

The most conspicuous object on the *posterior surface* of the petrous part of the bone is the **internal auditory meatus** (meatus acusticus internus) about 8 mm. deep in the adult, which has an oblique oval aperture and leads outwards and slightly downwards into the substance of the bone, giving passage to the auditory and facial nerves, together with the pars intermedia and the auditory branch of the basilar artery. The canal appears to end blindly; but if it be large, or still better, if part of it be cut away, its fundus will be seen to be crossed by a horizontal ridge, the **falciform crest**, which divides it into two fossæ, the floors of which (laminæ cribrosæ) are pierced by numerous small foramina for the branches of the auditory nerve and the vessels passing to the membranous labyrinth, whilst in the fore and upper part of the higher fossa the orifice of the **Fallopian aqueduct** (canalis facialis), through which the facial nerve passes, is seen leading in the direction of the hiatus Fallopii (see *ante*). External to the internal auditory meatus and above it, close to the superior border, an irregular depression, often faintly marked, with one or two small foramina opening into it, is to be noticed. This is the **floccular fossa** (fossa subarcuata), best seen in young bones, where it forms a distinct recess, which is bounded above by the bulging caused by the superior semicircular canal, within the concavity of which it is placed; it lodges a process of the dura mater. Below and external to this, separated from it by a smooth, elevated curved ridge, is the opening of the **aqueduct of the vestibule** (apertura externa aquæductus vestibuli), often concealed in a narrow curved fissure overhung by a sharp scale of bone. In this is lodged the saccus endolymphaticus. The ridge above it corresponds to the upper half of the posterior semicircular canal.

Connexions.—The temporal bone articulates with the malar, sphenoid, parietal, and occipital bones, and by a movable joint with the inferior maxilla. Occasionally the temporal articulates with the frontal, as happens normally in the anthropoid apes; although the region of the pterion (see p. 154) is characterised by an X-like form in the lower races of man there is no evidence that the occurrence of a fronto-squamosal suture is more frequent in the lower than the higher races, its occurrence being due to the manner of fusion of the so-called epipteric ossicles with the surrounding bones.

Architecture.—The temporal bone is remarkable for the hardness and density of its petrous part, wherein is lodged the osseous labyrinth which contains the delicate organs associated with the senses of hearing and equilibration. The **middle ear** or **tympanum** is a cavity which contains

the small auditory ossicles, and is separated from the external auditory meatus by the membrana tympani. *In front* it communicates with the pharynx by the Eustachian tube; *behind*, it opens into the mastoid antrum and mastoid air-cells by the aditus ad antrum. *Superiorly*, it is separated from the middle cranial fossa by a thin plate of bone called the tegmen tympani. *Inferiorly*, its floor is formed in part by the roof of the jugular fossa and the carotid canal. *Internally*, it is related to the structures which form the inner ear, notably the **cochlea** and **vestibule**, in front of which it is separated by a thin plate of bone from the carotid canal. Curving over the cavity of the tympanum is the aquæductus Fallopii, the thin walls of which are occasionally deficient. These details will be further dealt with in the section devoted to the Organs of Sense.

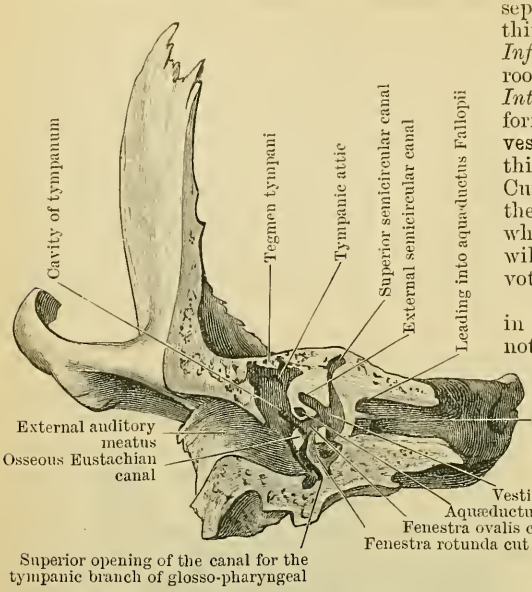


Fig. 91.—Vertical Transverse Section through Left Temporal Bone (Anterior Half of Section).

Variations.—The occurrence of a deficiency in the floor of the external auditory meatus is not uncommon in the adult. It is met with commonly in the child till about the age of five, and is due to incomplete ossification of the tympanic plate. The line of the petro-squamosal suture is occasionally grooved for the lodgment of a sinus (petro-squamosal); sometimes the posterior end of this is continuous with a canal which pierces the superior border of the bone and opens into the lateral sinus. Anteriorly the groove may pass into a canal which pierces the root of the zygoma and appears externally above the external extremity of the Glaserian fissure. These are the remains of channels through which the blood passed in the fœtal condition (see *ante*). Symington has described a case in which the squamous part was distinct and separate from the rest of the temporal bone in an adult; whilst Hyrtl has observed the division of the temporal squama into two by a transverse suture. P. P. Laidlaw (*Journ. Anat. and Physiol.* vol. xxxvii. p. 364) describes a temporal bone in which there was absence of the internal auditory meatus and of the stylo-mastoid foramen. The jugular fossa also was absent, and there was partial absence of the groove for the lateral sinus associated with the presence of a large mastoid foramen. An instance of a rudimentary condition of the carotid canal is also referred to in the same volume by G. H. K. Macalister.

G. Caribbe (*Anat. Anz.* vol. xx. p. 81) notes the occurrence in idiots and imbeciles of a more pronounced form of post-glenoid tubercle, and associates it with regressive changes in the development of the temporal bone.

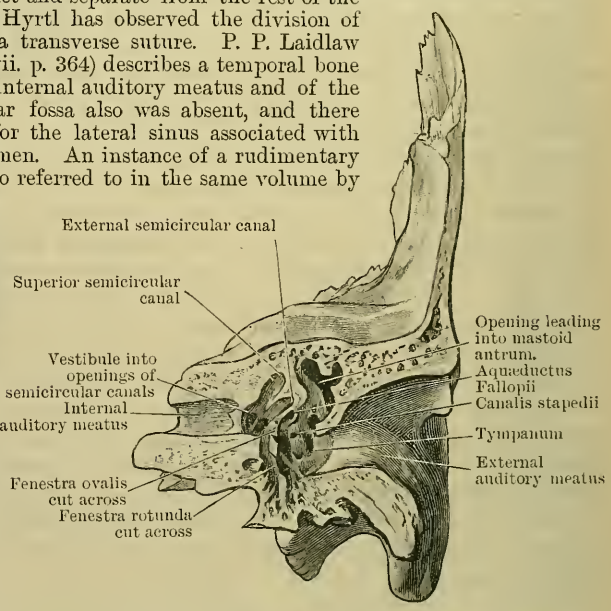


Fig. 92.—Vertical Transverse Section through Left Temporal Bone (Posterior Half of Section).

Ossification.—The petro-mastoid portion of the bone is developed by the deposition of earthy matter in the cartilaginous ear capsule and the perichondrium lining the labyrinth. The squamous and tympanic parts are ossified in membrane.

Ossification commences in the ear capsule in the fifth month, and proceeds so rapidly that by the end of the sixth month the individual centres are more or less fused. Of these, one which appears in the vicinity of the eminentia arcuata is the most definite in position and form; from this a lamina of bone of spiral form is developed, which covers in the inner limb of the superior semicircular canal, and forms the roof of the internal auditory meatus, together with the commencement of the Fallopian aqueduct. Reaching forwards, it extends to the apex of the petrous part; whilst externally it forms part of the inner

wall of the tympanum, surrounds the fenestra ovalis, and encloses within its substance portions of the cochlea, vestibule, and superior semicircular canal. Another centre appears in the vicinity of the promontory on the inner wall of the tympanum, surrounds the fenestra rotunda, forms the floor of the vestibule, and extends inwards to complete the floor of the internal auditory meatus. Surrounding the cochlea inferiorly and externally, it completes the floor of the tympanum, and ultimately blends with the fore and under part of the tympanic ring. The carotid canal at first grooves it, and is then subsequently surrounded by it. According to Lambertz the lamina spiralis of the cochlea ossifies in membrane. The roof of the tympanum is formed from a separate centre, which extends backwards towards the superior semicircular canal, and encloses the tympanic part of the aqueduct of Fallopius; externally this centre unites by suture with the squamosal, and sends down a thin process, which appears between the lips of the Glaserian fissure, and forms the outer wall of the Eustachian tube. Nuclei, either single or multiple, appear in the base of the petrous part, and envelop the posterior and external semicircular canals. It is by extension from this part that the mastoid process is ultimately developed. To these centres the terms pro-otic, opisthotic, pterotic, and epiotic, respectively, have been applied by Huxley and others. The **styloid process**, an independent development from the upper end of the cartilage of the second visceral arch, is ossified from two centres. The upper or basal appears before birth, and rapidly unites with the petro-mastoid, the tympanic plate encircling it in front. This represents the **tympanohyal** of comparative anatomy. At birth, or subsequent to it, another centre appears in the cartilage below the above: this is the **stylohyal**. Ankylosis usually occurs in adult life between the tympanohyal and stylohyal, the union of the two constituting the so-called styloid process of human anatomy.

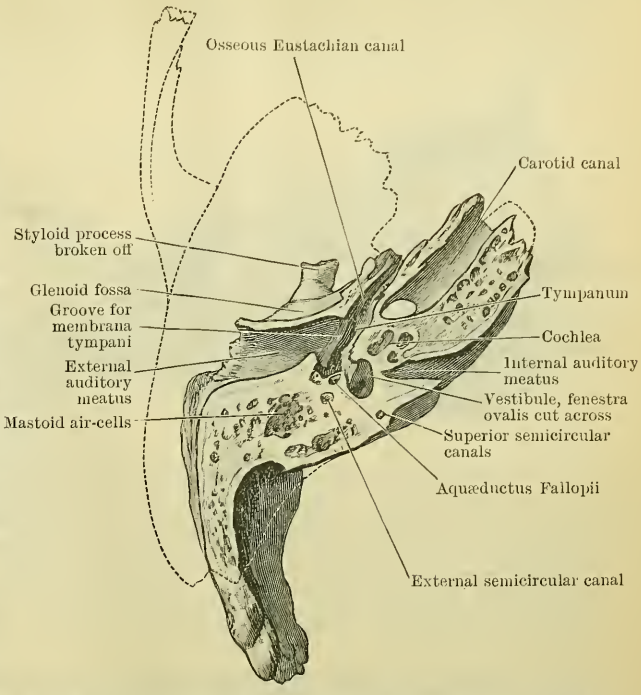


FIG. 93.—HORIZONTAL SECTION THROUGH LEFT TEMPORAL BONE (Lower Half of Section).

The centre from which the **squamo-zygomatic** develops appears in membrane about the end of the second month. Situated near the root of the zygoma, it extends forwards and outwards into that process, inwards to form the floor of the glenoid fossa, and upwards into the squamosal. From this latter there is a downward and backward extension, which forms the post-auditory process; this ultimately blends with the posterior limb of the tympanic ring, being separated from it in the adult by the auricular fissure. It forms the outer wall of the mastoid antrum, and constitutes the fore and upper part of the mastoid process in the adult. About the third month a centre appears in the outer membranous wall of the tympanum: from this the **tympanic ring** is developed. Incomplete above, it displays two free extremities. Of these, the anterior is somewhat enlarged, and unites in front with the glenoid portion of the squamo-zygomatic, being separated from it by the Glaserian fissure and the downgrowth from the tegmen tympani; the posterior joins the post-auditory process of the squamo-zygomatic above mentioned. Below, it blends internally with the portion of the petro-mastoid which forms the floor of the tympanum, and ensheathes the tympanohyal behind. From the outer side of the lower part of this ring two tubercles arise; these grow outwards, and so form the floor of the external auditory meatus. The interval between them remains unossified till about the age of five or six, after which closure takes place. This deficiency may, however, persist even in adult life (see *ante*, Variations).

At birth the temporal bone can usually be separated into its component parts. The

outer surface of the petrous part not only forms the inner wall of the tympanum, but is hollowed out behind and above to form the inner side of the mastoid antrum, the outer wall of which is completed by the post-auditory process of the squamo-zygomatic. As yet the mastoid process is undeveloped. It only assumes its nipple-like form about the second year. Towards puberty its cancellous tissue becomes permeated with air spaces,

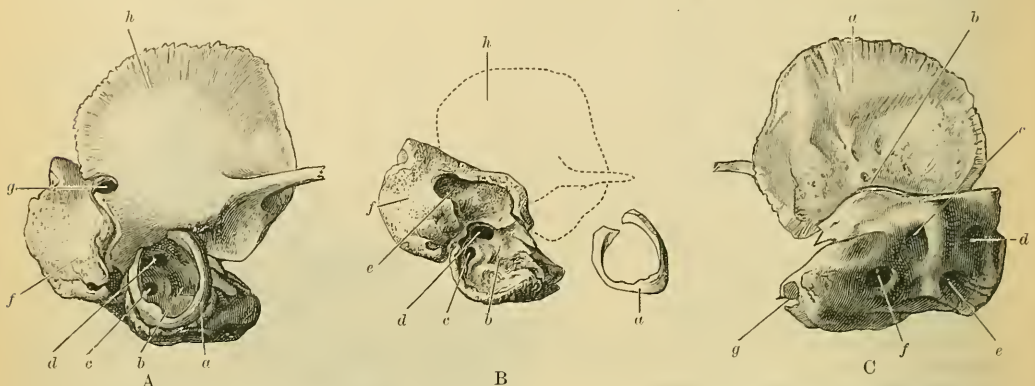


Fig. 94.—A. The Outer Surface of the Right Temporal Bone at Birth. B. The same with Squamo-zygomatic Portion Removed.

(The lettering is the same in both A and B.) *a*, Tympanic ring. *b*, Inner wall of tympanum. *c*, Fenestra rotunda. *d*, Foramen ovale. *e*, Mastoid. *f*, Mastoid process. *g*. Masto-squamosal suture, with foramen for transmission of vessels. *h*, Squamo-zygomatic, removed in figure B to show how its descending process forms the outer wall of the mastoid antrum.

Fig. 94.—C. Inner Surface of the Right Temporal Bone at Birth.

a, Squamo-zygomatic. *b*, Petro-squamosal suture and foramen (just above the end of the lead line). *c*, Subarcuate fossa. *d*, Aquæductus vestibuli. *e*, Aquæductus cochleæ. *f*, Internal auditory meatus. *g*, Upper end of carotid canal.

which are in communication with and extensions from the mastoid antrum. The external auditory meatus is unossified in front and below, the outgrowth from the tympanic ring occurring subsequent to birth. The glenoid fossa is shallow and everted; the jugular fossa is ill-marked; whilst the subarcuate fossa is represented by a deep pit, the so-called floccular fossa of comparative anatomy. The hiatus Fallopii is an open groove, displaying at either end the openings of the inner and outer portions of the Fallopian aqueduct.

The Sphenoid Bone.

The **sphenoid bone** (os sphenoidale) lies in front of the basi-occipital mesially, and the temporals on either side. It enters into the formation of the cranial, orbital, and nasal cavities, as well as the temporal, zygomatic, pterygoid, and spheno-maxillary fossæ. It consists of a body with three pairs of expanded processes, the great wings, the lesser wings, and the pterygoid processes.

The **body** (corpus), more or less cubical in form, is hollow, and contains within it the two large **sphenoidal air sinuses**. These are separated by a partition, which is usually deflected to one or other side of the middle line. Each sinus extends outwards for a short distance into the root of the great wing, and downwards and outwards towards the base of the pterygoid process of the same side. They communicate by apertures with the upper and back part of the nasal fossæ. In the adult the *posterior aspect* of the body displays a sawn surface due to its separation from the basi-occipital with which in the adult it is firmly ankylosed. The *superior surface*, from the fore angles of which the lesser wings arise, displays an appearance comparable to that of an oriental saddle, over its middle there is a deep depression, the **sella turcica** or **pituitary fossa** (fossa hypophyseos), in which is lodged the pituitary body. Behind, this is overhung by a sloping ridge, the **dorsum sella**, the posterior surface of which is inclined upwards, and is in continuation with the basilar groove of the occipital bone. Anteriorly and externally the angles of this ridge project over the pituitary fossa in the form of prominent tubercles, called the **posterior clinoid processes** (processus clinoidei posteriores). In front of the pituitary fossa there is a transverse elevation, the **olivary eminence** (tuberculum sellæ), towards the outer extremities of which, and somewhat behind, there are often-

times little spurs of bone, the **middle clinoid processes** (processus clinoidei medii). In front of the olivary eminence is the **optic groove** (sulcus chiasmatis), which passes outwards on either side to become continuous, between the roots of the lesser wings, with the optic foramina.

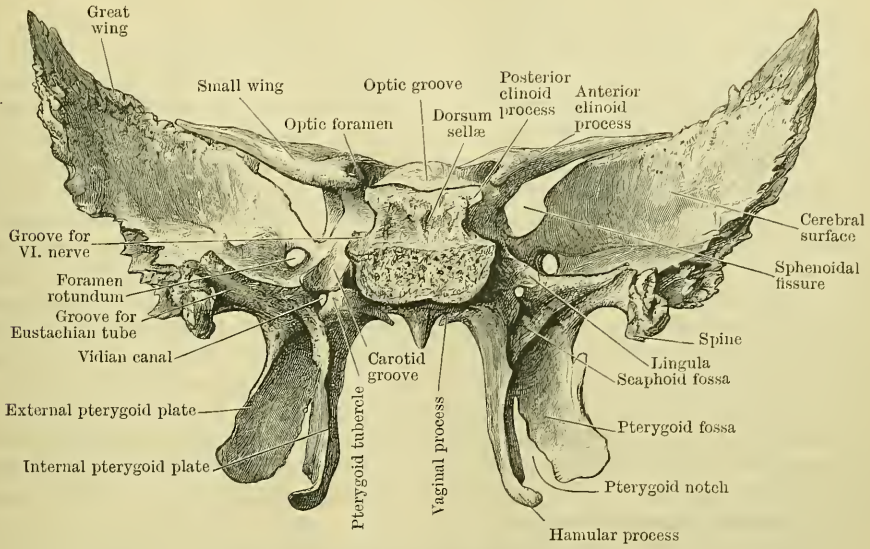


FIG. 95.—SPHENOID AS SEEN FROM BEHIND.

This groove is liable to considerable variations, and apparently does not always serve for the lodgment of the optic chiasma. (Lawrence, "Proc. Soc. Anat.," *Journ. Anat. and Physiol.* vol. xxviii. p. 18.)

In front of the optic groove, from which it is often separated by a thin sharp edge, the superior surface continues forwards on the same plane as the upper surfaces of

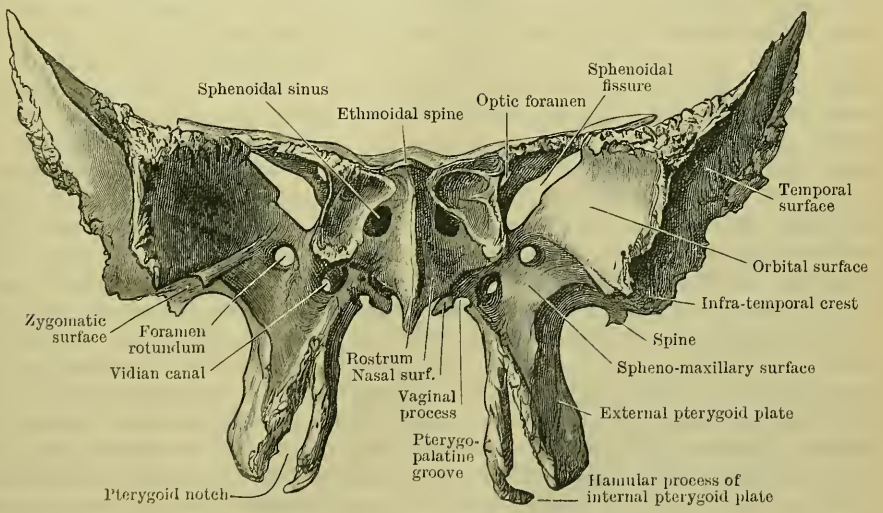


FIG. 96.—SPHENOID AS SEEN FROM THE FRONT.

the lesser wings, and terminates anteriorly in a ragged edge, which articulates with the cribriform plate of the ethmoid, and has often projecting from it, mesially, a pointed process, the **ethmoidal spine**. The *lateral aspects* of the body are fused with the great wings, and in part also with the roots of the pterygoid processes. Curving along the side of the body, superior to its attachment to the great wing, is an ʃ-shaped groove, the **carotid groove** (sulcus caroticus), which marks the

position and course of the internal carotid artery. Posteriorly, the hinder margin of this groove, formed by the salient outer edge of the posterior surface of the body, articulates with the apex of the petrous portion of the temporal bone, and is hence called the **petrosal process**; just above this, on the lateral border of the dorsum sellæ, there is often a groove for the sixth nerve.

The *anterior surface* of the body displays a vertical mesial **sphenoidal crest** (crista sphenoidalis), continuous above with the ethmoidal spine, and below with the pointed projection called the rostrum. This crest articulates in front with the perpendicular plate of the ethmoid. On either side of the middle line are seen the irregular openings leading into the sphenoidal air sinuses, the thin anterior walls of which are in part formed by the absorption of the sphenoidal turbinated bones with which in early life they are in contact. With the exception of a broad groove leading downwards from the apertures above mentioned, which enters into the formation of the roof of the nasal fossa of the corresponding side, the lateral aspects of this surface of the bone are elsewhere in articulation with the lateral masses of the ethmoid and the orbital processes of the palate bones. The **rostrum** is continued mesially for some distance along the *inferior surface* of the body, where it forms a prominent keel which fits into the recess formed by the alæ of the vomer. The edges of the latter serve to separate the rostrum from the incurved vaginal processes at the roots of the internal pterygoid plates. Posteriorly the under surface of the body of the sphenoid is rougher, and covered by the mucous membrane of the roof of the pharynx; here, occasionally, a median depression may be seen which marks the position of the inferior extremity of a fœtal channel, called the **canalis cranio-pharyngeus.**

The **lesser or orbital wings** (alæ parvæ) are two flattened triangular plates of bone which project forwards and outwards from the fore and upper part of the body of the bone, with which they are united by two roots which enclose between them the **optic foramina** (foramina optica) for the transmission of the optic nerves and ophthalmic arteries. Of these roots, the posterior springs from the body just wide of the olivary eminence, separating the carotid groove behind from the optic foramen in front; externally this root is confluent with the recurved posterior angle of the lesser wing, forming the projection known as the **anterior clinoid process** (processus clinoideus anterior), which overhangs the fore part of the body of the bone. The anterior root, broad and compressed, unites the upper surface of the lesser wing with the fore and upper part of the body. Externally the outer angle terminates in a pointed process which reaches the region of the pterion and there articulates with the frontal, and may come in contact with the great wing. The superior aspect is smooth, and forms in part the floor of the anterior cranial fossa. The inferior surface constitutes part of the posterior portion of the upper wall of the orbit, and also serves to roof in the **sphenoidal fissure** which separates the lesser from the greater wings below. The anterior edge is ragged and irregular, and articulates with the orbital plates of the frontal. The posterior margin, sharp and sickle-shaped, separates the anterior from the middle cranial fossa, and corresponds to the position of the Sylvian fissure on the surface of the cerebrum.

The **greater or temporal wings** (alæ magnæ), as seen from above, are of a somewhat crescentic form. If the inner convex edge of the crescent be divided into fifths, the posterior fifth extends backwards and outwards beyond the body of the bone, presenting a free posterior edge, which forms the anterior boundary of the foramen lacerum medium. This border ends behind in the horn of the crescent, from which a pointed process projects downwards, called the **alar or sphenoidal spine** (spina angularis), this is wedged into the angle between the petrous and squamous parts of the temporal bone. The inner surface of the posterior border and spine is furrowed for the cartilaginous **Eustachian tube** (sulcus tubæ), whilst on the inner side of the spine the course of the chorda tympani nerve is indicated by a groove (Lucas). The second fifth of the convex border of the crescent is fused to the side of the body and united below with the root of the pterygoid process. The angle formed by the union of the great wing with the side of the body posteriorly corresponds to the hinder end of the carotid groove, the outer lip of which is formed by a projecting lamina called the **lingula.** The remaining three-fifths of the convex

border is divisible into two nearly equal parts; the inner is a free, curved, sharp margin, which forms the inferior margin of the **sphenoidal fissure** (fissura orbitalis superior), the cleft which separates the great wing from the lesser wing, and which establishes a wide channel of communication between the middle cranial fossa and the cavity of the orbit, transmitting the third, fourth, ophthalmic division of the fifth, and the sixth cranial nerves, together with the ophthalmic veins. Wide of the sphenoidal fissure this edge becomes broad and serrated, articulating with the frontal bone internally, and at the part corresponding to the anterior horn of the crescent, by a surface of variable width, it unites with the anterior inferior angle of the parietal bone. The *external border* corresponds to the concave side of the crescent, and is serrated for articulation with the squamous temporal, being thin and bevelled at the expense of its outer surface above and externally, and broad and thick behind as it passes towards the alar spine. The *superior* or *cerebral surface* is concave from behind forwards, and in its fore part from side to side also; it forms a considerable part of the floor of the middle cranial fossa, and bears the impress of the convolutions of the extremity of the temporal lobe of the cerebrum which rests upon it; towards its outer side it is grooved obliquely by an anterior branch of the middle meningeal artery. The following foramina pierce the great wing: close to and in front of the alar spine is the **foramen spinosum** for the transmission of the middle meningeal artery and its companion vein, together with a recurrent branch from the third division of the V. nerve. In front of and internal to this, and close to the posterior free border, is the **foramen ovale**, of large size and elongated form. This gives passage to the motor root and inferior sensory division of the V. nerve, and admits the small meningeal branch of the middle meningeal artery; a small emissary vein from the cavernous sinus usually passes through this foramen, and occasionally also the small superficial petrosal nerve. Near the fore part of the root of the great wing, and just below the sphenoidal fissure, is the **foramen rotundum**, of smaller size and circular form. Through this the second division of the V. nerve escapes from the cranium. Occasionally there is a small canal—the **foramen of Vesalius**—which pierces the root of the great wing to the inner side of the foramen ovale. This opens below into the scaphoid fossa at the base of the internal pterygoid plate, and transmits a small vein. Occasionally there is a small foramen (canaliculus innominatus) to the inner side of the foramen spinosum for the transmission of the small superficial petrosal nerve.

The *outer surface* of the great wing is divided into three well-marked areas; of these the upper two are separated by an oblique jagged ridge, the **malar crest** (margo zygomaticus), for articulation with the orbital process of the malar bone. The lower part of this ridge may occasionally articulate with the malar process of the superior maxilla. Of these two areas the **orbital** (facies orbitalis) is directed forwards and a little inwards; of quadrilateral shape, it forms the back and outer wall of the orbit; plane and smooth, it is bounded behind by the sharp inferior free margin of the sphenoidal fissure, towards the inner extremity of which a pointed spine for the attachment of the inferior common ligament of origin of the ocular muscles can usually be seen. It is limited superiorly by the edge of a rough triangular area which articulates with the frontal bone; anteriorly by the malar crest; whilst inferiorly a free, well-defined horizontal margin constitutes the posterior and external boundary of the spheno-maxillary fissure (fissura orbitalis inferior), which separates this part of the bone from the orbital plate of the superior maxilla. Below this border there is a grooved surface which leads inwards toward the orifice of the foramen rotundum. In the articulated skull this forms part of the posterior wall of the spheno-maxillary fossa.

To the outer side of the malar crest, which bounds it in front, is the **temporal area** (facies temporalis), concavo-convex from before backwards. It slopes inwards below, where it is separated from the zygomatic area by a well-marked muscular ridge, the **infra-temporal crest** or **pterygoid ridge** (crista infratemporalis). Behind, the temporal surface is bounded by the margin of the great wing which articulates with the squamous temporal, and above by the edge which unites it with the anterior inferior angle of the parietal and the frontal bone. The temporal surface

enters into the formation of the floor of the fossa of the same name, and affords an extensive attachment to the fibres of origin of the temporal muscle. The **zygomatic surface** (facies infratemporalis), situated below the infra-temporal crest, corresponds to the under surface of the posterior half of the great wing; it extends as far back as the alar spine and posterior border. Opening on it are seen the orifices of the foramen spinosum and ovale. It is slightly concave from side to side, and is confluent internally with the outer surface of the external pterygoid plate. In front it is bounded by a ridge which curves upwards and outwards from the fore part of the external pterygoid plate to join the infratemporal crest. In the articulated skull this ridge forms the posterior boundary of the pterygo-maxillary fissure. The zygomatic surface overhangs the zygomatic fossa, and affords an origin for the upper head of the external pterygoid muscle.

The **pterygoid processes** (processus pterygoidei) spring from the inferior surface of the lateral aspect of the body as well as the under side of the root of the great wings, and pass vertically downwards. Each consists of two laminæ, the external and internal pterygoid plates, fused together anteriorly, and enclosing between them posteriorly the **pterygoid fossa** (fossa pterygoidea). The **external pterygoid plate** (lamina lateralis processus pterygoidei), thin and expanded, is directed obliquely backwards and outwards, its lower part being often somewhat everted. Its hinder edge is sharp, and often has projecting from it one or two spines, to one of which (processus pterygo-spinosus) the pterygo-spinous ligament which stretches towards the alar spine is attached. Externally it furnishes an origin for the lower head of the external pterygoid muscle, and on its inner side, where it forms the lateral wall of the pterygoid fossa, it supplies an attachment for the internal pterygoid muscle.

The **internal pterygoid plate** (lamina medialis processus pterygoidei) is narrower and somewhat stouter. By its inner aspect it forms the posterior part of the lateral wall of the nasal fossæ; externally it is directed towards the pterygoid fossa. Its posterior edge ends below in the hook-like **hamular process** (hamulus pterygoidei), which, reaching a lower level than the external plate, curves backwards and outwards, furnishing a groove in which the tendon of the tensor palati muscle glides; superiorly, the sharp posterior margin of the inner plate bifurcates, so as to enclose the shallow **scaphoid fossa** from which the tensor palati muscle arises, and wherein may occasionally be seen the inferior aperture of the foramen Vesalii. To the inner edge of this fossa, as well as to the posterior border of the internal pterygoid plate, the pharyngeal aponeurosis is attached. Here, too, the cartilage of the Eustachian tube is supported on a slight projection, and the palato-pharyngeus muscle receives an origin, whilst the superior constrictor of the pharynx arises from the lower third of the same border and from the hamular process. Superiorly and internally the inner plate forms an incurved lamina of bone, the **vaginal process** (processus vaginalis), which is applied to the under surface of the lateral aspect of the body reaching inwards, towards the root of the rostrum, from which, however, it is separated by a groove, in which, in the articulated skull, the ala of the vomer is lodged. The angle formed by the vaginal process and the internal edge of the scaphoid fossa forms a projection called the **pterygoid tubercle**, immediately above which is the posterior aperture of the **Vidian canal** (canalis pterygoideus), through which the Vidian nerve and artery are transmitted. On its under surface the vaginal process displays a groove (sulcus pterygo-palatinus) which in the articulated skull is converted into the **pterygo-palatine canal** by its union with the palate bone. In front, at its root, the pterygoid process displays a broad smooth surface (facies spheno-maxillaris), which is confluent above with the root of the great wing around the foramen rotundum, and forms the posterior wall of the spheno-maxillary fossa. Here, to the inner side of the foramen rotundum, is seen the anterior opening of the **Vidian canal**. Below, the pterygoid plates are separated by an angular cleft, the **pterygoid notch** (fissura pterygoidea); in this is lodged the tuberosity of the palate bone, the margins of which articulate with the serrated edges of the recess.

Connexions.—The sphenoid articulates with the occipital, temporals, parietals, frontal,

ethmoid, sphenoidal turbinals, vomer, palate and malar bones, and occasionally with the superior maxillæ.

Architecture.—In the adult the body of the bone is hollow and encloses the sphenoidal air cells, usually two in number, separated by a septum. The arrangement and extent of these air cells vary; sometimes they are multilocular, at other times simple, while occasionally they extend backwards into the basi-occipital and outwards and downwards into the roots of the great wings and pterygoid processes. Cases are on record in which in the adult the body of the bone was not pneumatic.

Variations.—Through imperfect ossification the foramen spinosum and foramen ovale are sometimes incomplete posteriorly. Le Double (*Bull. et mém. de la Soc. d'Anth. de Paris*, 5e ser. vol. iii. p. 550), records a case in which the foramen rotundum and the sphenoidal fissure were united so as to form a single cleft.

Through deficiency of its external wall, the optic foramen, in rare instances, communicates with the sphenoidal fissure. Duplication of the optic foramen is also recorded as a rare occurrence, the artery passing through one canal, the nerve through the other. Persistence of the cranio-pharyngeal canal is also occasionally met with. On the other hand, owing to the ossification of fibrous bands connecting the several bony points, anomalous foramina are frequently met with. Cases of persistence of the cranio-pharyngeal canal have been recorded.

Ossification.—The sphenoid of man is formed by the fusion of two parts, the **pre-sphenoid** and the **post-sphenoid**, each associated with certain processes. In most mammals the orbito-sphenoids or lesser wings fuse with the pre-sphenoid, whilst the alisphenoids or greater wings, together with the internal pterygoid plate, ankylose with the post-sphenoid. The ossification of these several parts takes place in cartilage, with the exception of the internal pterygoid plate, which is developed from an independent centre in the connective tissue of the lateral wall of the oral cavity (Hertwig).

At the end of the second month a centre appears in the root of the great wing between the foramen ovale and foramen rotundum; from this the ossification spreads outwards and backwards and also downwards into the external pterygoid plate. Meanwhile two centres appear about the same time in the basi-sphenoid in relation to the floor of the sella turcica and on either side of the cranio-pharyngeal canal, around which they ossify, ultimately leading to the obliteration of this channel. Somewhat later a centre appears on either side, from which the lateral aspect of the body and the lingula are developed. Fusion between these four centres is usually complete by the sixth month.

In the pre-sphenoid a pair of lateral nuclei make their appearance about the middle of the third month, just external to the optic foramina; from each of these the orbito-sphenoids (lesser wings) and their roots are developed. About the same time another pair of centres, placed mesial to the optic foramina, constitute the body of the pre-sphenoid. By the coalescence of these in front, and their ultimate union with the basi-sphenoid behind, a cartilaginous interval is enclosed, of triangular shape, which, however, becomes gradually reduced in size by the ingrowth of its margins so as to form two mesially-placed foramina, as may be frequently observed in young bones—one opening on the surface of the olivary eminence, the other being placed anteriorly. (Lawrence, "Proc. Soc. Anat.," *Journ. Anat. and Physiol.* vol. xxviii. p. 19.)

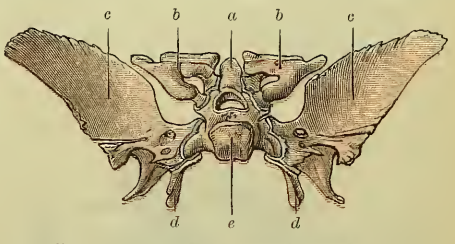


Fig. 97.—Ossification of Sphenoid.

a, Pre-sphenoid; *b*, Orbito-sphenoids; *c*, Alisphenoids; *d*, Internal pterygoid plates; *e*, Basi-sphenoid.

As has been seen, the internal pterygoid plates are developed in membrane and are the first parts of the sphenoid to ossify. (Fawcett, *Anat. Anz.*, vol. xxvi. 1905, p. 280.) Each is derived from a single nucleus which appears about the ninth or tenth week, and fuses with the under surface of the great wing, there forming a groove which is converted into the Vidian canal when the alisphenoid and internal pterygoid plates fuse later with the body of the post-sphenoid. The hamular process, however, chondrifies before it ossifies during the third month. Fawcett also regards the external pterygoid plate as of membranous origin.

At birth the sphenoid consists of three parts: one comprising the orbito-sphenoids together with the body of the pre-sphenoid and the basi-sphenoid, the others consisting of the alisphenoids, one on either side. Fusion of the latter with the former occurs near the end of the first year. The dorsum sella at birth consists of a cartilaginous plate which separates the body of the post-sphenoid from the basi-occipital. This slowly ossifies, but the cartilage does not entirely disappear till the age of twenty-five, by which time bony ankylosis of the basi-cranial axis is complete. For a considerable time the under surface of the

body of the pre-sphenoid displays a bullate appearance, with the sides of which the sphenoidal turbinated bones articulate. It is only after the seventh or eighth year is reached that the cancellous tissue within this part of the bone becomes absorbed to form the sphenoidal sinuses.

The **sphenoidal turbinals** (conchæ sphenoidales), or bones of Bertin, best studied in childhood, are formed by the fusion of four distinct ossicles (Cleland), the centres for which appear in the later months of utero-gestation. Each bone consists of a hollow, three-sided pyramid, the apex of which is in contact with the fore part of the vaginal process of the internal pterygoid, whilst the base fits on to the posterior surface of the lateral mass of the ethmoid. The *inferior surface* of each forms the roof of the corresponding nasal fossa, and completes the formation of the spheno-palatine foramen, whilst the external aspect is united with the palate bone and forms the inner wall of the spheno-maxillary fossa, and occasionally constitutes a part of the orbital wall posterior to the os planum of the ethmoid. The *superior surface* of the sphenoidal turbinal is applied to the fore and under surface of the body of the pre-sphenoid on either side of the rostrum. It is by the absorption of this wall that the sphenoidal sinuses are ultimately opened up. The base of the pyramid forms the aperture through which each of these sinuses opens into the nasal fossæ in the adult. Owing to their firm ankylosis with the surrounding bones, these ossicles are merely represented in the adult disarticulated skull by the irregular fragments adherent to the separated borders of the ethmoid, palate, and sphenoid bones.

The Ethmoid Bone.

The **ethmoid bone** (os ethmoidale) lies in front of the sphenoid, and occupies the interval between the orbital plates of the frontal, thus entering into the formation of the anterior cranial fossa as well as the inner walls of the orbits and the roof and inner and outer walls of the nasal fossæ. The bone, which is extremely light, consists of two cellular parts—the **lateral masses**, which are united superiorly to a mesial **vertical plate** by a thin horizontal lamina which, from its perforated condition, is called the **cribriform plate.**

The study of this bone will be much facilitated by cutting through the cribriform plate on one side of the vertical plate, thus removing the lateral mass of one side and exposing more fully the central perpendicular lamina.

The **vertical plate** (lamina perpendicularis), of irregular pentagonal shape, forms the upper part of the nasal septum. Its superior border projects above the level of the cribriform plate so as to form a crest, which is much elevated anteriorly, where it terminates in a bullate process called the **crista galli**, the upper edge of which is sharp and pointed, and affords attachment to the falx cerebri. In front of this process there is a groove which separates the **alar processes** (processus alares) which project from the crista galli on either side. By articulation with the frontal bone this groove is converted into a canal, the **foramen cæcum**; this, however, is not always blind, but frequently transmits a vein to the roof of the nose. The *posterior margin* of the vertical plate is thin, and articulates with the crest of the sphenoid. The *posterior inferior border* in the adult is ankylosed with the vomer; and the *anterior inferior edge*, which is usually thicker than the others, unites with the cartilaginous nasal septum. The *anterior superior border* articulates with the nasal spine of the frontal bone and with the median crest formed by the union of the two nasal bones. The vertical plate, which is usually deflected to one or other side, has generally smooth *surfaces*, except above, where they are channelled by

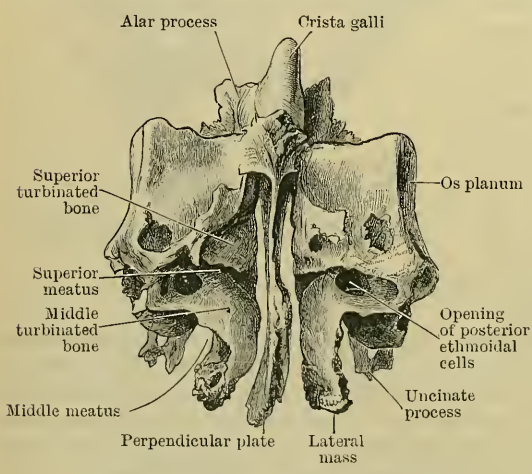


Fig. 98.—Ethmoid as seen from Behind.

short and shallow grooves leading to the foramina which pierce the cribriform plate; these are for the lodgment of the olfactory nerves.

The **lateral mass** or **labyrinth** (labyrinthus) is composed of papery bone, enclosing a large number of air-cells; these are arranged in three groups—an anterior, a middle, and a posterior, the walls of which have been broken in front, above, behind, and below, in the process of disarticulation. Externally they are closed in by a thin, oblong lamina, the **orbital plate** or **os planum** (lamina papyracea), which forms a part of the inner wall of the orbit, and articulates *above* with the orbital plate of the frontal, which here roofs in the ethmoidal cells. The line of this suture is pierced by two canals, the **anterior** and **posterior ethmoidal canals**, both of which transmit small ethmoidal vessels, whilst the anterior also gives passage to the nasal nerve. *In front* the os planum articulates with the lachrymal bone; whilst *below*, by its union with the orbital surface of the superior maxillary bone, the air-sinuses in both situations are completed. *Posteriorly* the os planum articulates with the sphenoid, and at its posterior inferior angle for a variable distance with the orbital process of the palate bone, both of which serve to close in the air-cells. The *mesial aspect* of the **lateral mass** displays the convoluted **turbinated processes**, usually two in number, though occasionally there may be three—rarely more. In cases where there are two **ethmo-turbinals** they are separated posteriorly by a deep groove. A channel is thus formed in the back part of the lateral and upper aspect of the nasal fossæ, called the **superior meatus**, which is roofed in by the superior **turbinated process** (concha superior), whilst its floor is formed by the upper surface of the **middle turbinated process** (concha media). The posterior ethmoidal cells open into this meatus. In front of the superior meatus, which only grooves the posterior half of this aspect of the bone, the surface is rounded from above downwards and before backwards, and forms the inner wall of the anterior and middle ethmoidal cells. Running obliquely from above downwards and backwards over the mesial surface of the superior concha, are a number of fine grooves continuous above with the foramina in the cribriform plate; these are fewer and more scattered in front, do not pass on to the middle concha, and are for the olfactory nerves.

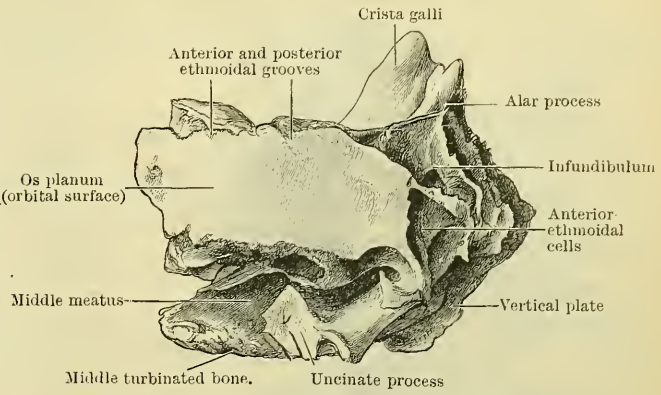


Fig. 99.—Ethmoid as seen from the Right Side.

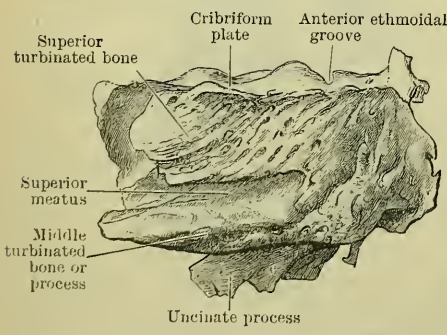


Fig. 100.—Section showing Nasal Aspect of Left Lateral Mass of Ethmoid.

The **middle turbinated process** (concha media) is nearly twice the length of the superior. Its anterior extremity is united for a short distance to the superior turbinated crest on the inner side of the frontal process of the superior maxilla. By its thickened, free convoluted border it overhangs a deep groove which runs along the under surface of the lateral mass. This is the **middle meatus of the nose**. It receives the openings of the middle ethmoidal cells and a passage which runs upwards and forwards from it, the **infundibulum**. This communicates with the anterior ethmoidal cells and the frontal sinus. The outer side of the middle meatus is formed by the thin inner

walls of the ethmoidal cells. Curving downwards, backwards, and a little outwards from the roof of the fore-part of this meatus is the **uncinate process** (processus uncinatus). This bridges across the irregular opening on the inner wall of the maxillary sinus, and articulates inferiorly with the ethmoidal process of the inferior turbinated bone. The hinder extremity of the middle turbinated bone articulates with the ethmoidal crest on the vertical plate of palate bone.

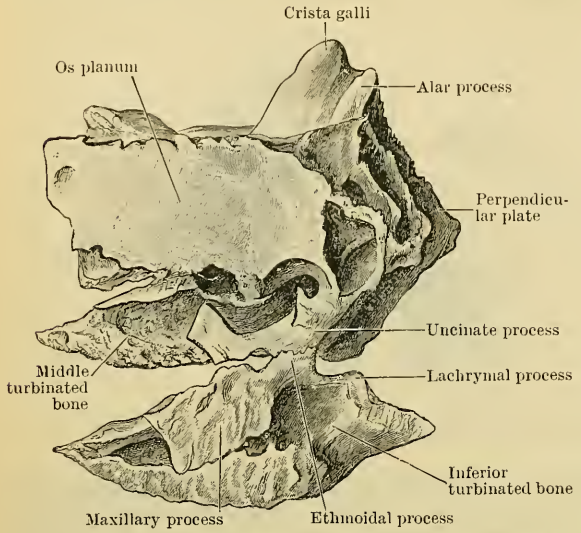


Fig. 101.—Showing Articulation of Inferior Turbinated Bone with Ethmoid.

The **cribriform plate** (lamina cribrosa) is the horizontal lamina which connects the lateral masses with the vertical plate, much in the same manner as the cross limb of a capital T is arranged. It occupies the interval between the orbital plates of the frontal bone, roofing in the nasal fossæ inferiorly, and superiorly forming on either side of the crista galli two shallow **olfactory grooves** in which, in the recent condition, the olfactory lobes of the cerebrum are lodged. Numerous foramina for the transmission of the olfactory nerves pierce this part of the bone; those to the inner and outer sides of the groove are the largest and most regular in their arrangement. Along the outer edges of the cribriform plate two notches can usually be distinguished; when articulated with the frontal bone these form the inner openings of the **ethmoidal canals**. Leading forward from the anterior of these there is often a groove which crosses to the side of the crista galli, where it ends in a slit which allows of the transmission of the nasal nerve to the nose. Posteriorly the cribriform plate articulates with the ethmoidal spine of the sphenoid.

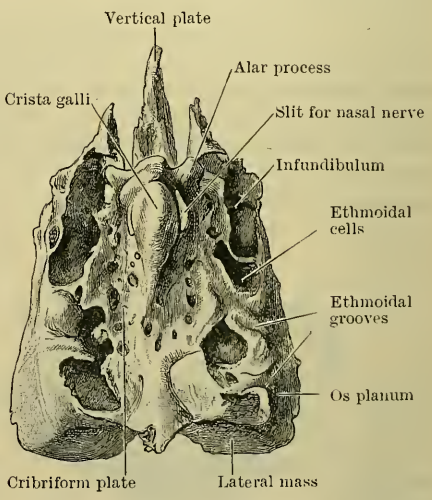


Fig. 102.—Ethmoid as seen from Above.

Connexions.—The ethmoid articulates with the sphenoid and sphenoidal turbinals, the frontal, the two nasals, two superior maxillæ, two lachrymals, two inferior turbinals, two palates, and the vomer.

Variations.—The size of the os planum is liable to considerable variations. In the lower races it tends to be narrower from above downwards than in the higher, in this respect resembling the condition met with in the anthropoids. The os planum may fail to articulate with the lachrymal owing to the union of the frontal with the orbital process of the superior maxilla in front of it. (Orbito-maxillary frontal suture. A. Thomson, *Journ. Anat. and Physiol.* vol. xxiv. p. 349.) Division of the os planum by a vertical suture into an anterior and posterior part has been frequently recorded. The number of the turbinals may be increased from two to four, or may be reduced to one. (Report of Committee of Collect. Invest., *Journ. Anat. and Physiol.*, vol. xxviii. p. 74.)

Ossification takes place in the cartilage of the nasal capsule. Each lateral mass has one centre, which appears about the fourth or fifth month in the neighbourhood of the os planum. From this the laminæ around the ethmoidal air cells are formed which are complete at birth, the air-sinuses in this instance not being formed by the absorption of cancellous bone. From these centres the turbinals are also developed, and these, too, are ossified at the ninth month.

At birth the ossified lateral masses are united to the central cartilaginous plate by a fibrous layer. Two centres make their appearance in the mesial cartilage on either side of the root of the crista galli about the end of the first year; from these, the crista galli and the vertical plate are ossified as well as the mesial part of the cribriform plate, the lateral portions of which are derived from an inward extension of the lateral mass.

Ossification is usually complete about the fifth or sixth year. About the twenty-fifth year bony union has taken place between the cribriform plate and the sphenoid, but ankylosis between the vertical plate and the vomer is not usual till the fortieth or forty-fifth year.

Wormian Bones.

Along the line of the cranial sutures and in the region of the fontanelles, isolated bones of irregular form and variable size are occasionally met with. These are the so-called Wormian bones, named after the Danish anatomist Wormius. They are also called sutural or epactal bones. Their presence depends on the fact that they are either developed from distinct ossific nuclei, or it may be from a division of the primary ossific deposit. Their occurrence may also be associated with certain pathological conditions which modify the development of the bone. They usually include the whole thickness of the cranial wall, or it may be only involve the outer or inner tables of the cranial bones. They are most frequent in the region of the lambda and the lambdoid suture. They occur commonly about the pterion, and in this situation are called epipteric bones (Flower). By their fusion with one or other of the adjacent bones they here lead to the occurrence of a fronto-squamosal suture. Their presence has also been noted along the line of the sagittal suture, and sometimes in metopic skulls in the inter-frontal suture. They are occasionally met with at the asterion and more rarely at the obelion. They appear less frequently in the face, but their presence has been noted around the lachrymal bone, and also at the extremity of the spheno-maxillary fissure, where they may form an independent nodule wedged in between the great wing of the sphenoid, the malar, and the superior maxillary bones.

BONES OF THE FACE.

The bones of the face (ossa faciei), fourteen in number, comprise two superior maxillæ, two palates, two malars, two lachrymals, and two nasals, together with the vomer and inferior maxilla.

The Superior Maxillary Bones.

The **superior maxillæ** (maxillæ), of which there are two, unite to form the upper jaw. Each consists of a **body**, with which are connected four projections, named respectively the **zygomatic, frontal, alveolar**, and **palatal processes.**

The **body** (corpus) is of pyramidal form, and contains within it a hollow called the **antrum** or **maxillary air-sinus**. It has four surfaces—an antero-external or facial, a postero-external or zygomatic, a supero-external or orbital, and an internal or nasal. The *antero-external* or **facial surface** (facies anterior) is confluent below with the alveolar process. Above, it is separated from the orbital aspect by the **infraorbital margin** (margo infraorbitalis), whilst internally it is limited by the free margin of the **nasal notch**, which ends below in the pointed **anterior nasal spine** (spina nasalis anterior). Posteriorly it is separated from the zygomatic surface by the inferior border of the **zygomatic process.** The facial aspect of the bone is ridged by the sockets of the teeth (juga alveolaria). The ridge corresponding to the root of the canine tooth is usually the most pronounced; internal to this, and overlying the roots of the incisor teeth, is the shallow **incisive** or **myrtiform fossa**, whilst placed externally, on a higher level, is the deeper **canine fossa**, the floor of which is formed in part by the projecting zygomatic process. Above this, and near the infraorbital margin, is the **infraorbital foramen**, the external opening of the infraorbital canal, which transmits the infraorbital nerve and artery. The *postero-external* or **zygomatic surface** is separated above from the orbital aspect by a rounded free edge, which forms the anterior margin of the **spheno-maxillary fissure** in the articulated skull. Inferiorly and in front it is separated from the facial surface by the zygomatic process and its free lower border. Internally it is limited

by a sharp, irregular margin with which the palate bone articulates. This surface is more or less convex, and is directed towards the zygomatic and spheno-maxillary fossæ. It is pierced in a downward direction by the apertures of the **posterior dental canals** (foramina alveolaria), two or more in number, which transmit the corresponding nerves and vessels to the molar teeth. Its lower part, slightly more prominent where it overhangs the root of the wisdom molar, is often called the **tuberosity** (tuber maxillare). The *supero-external* or **orbital surface** (planum orbitale), smooth and plane, is triangular in shape and forms part of the floor of the orbit. Its anterior edge corresponds to the infraorbital margin; its posterior border coincides with the anterior boundary of the spheno-maxillary fissure. Its thin inner edge, which may be regarded as the base of the triangle, is notched in front to form the **lachrymal groove** (sulcus lacrimalis), behind which it articulates with the lachrymal bone for a short distance, then for a greater length with the os planum of the ethmoid, and terminates posteriorly in a surface for articulation with the orbital process of the palate bone. Its external angle corresponds to the outspring of the zygomatic process. Traversing its substance is the **infraorbital canal**, the anterior opening of which has been already noticed on the facial aspect of the body. Behind, however, owing to deficiency of its roof, the canal forms a groove which lips the edge of the bone which constitutes the anterior boundary of the spheno-maxillary fissure. If this canal be laid open, the orifices of the middle and anterior dental canals will be seen, which transmit the corresponding vessels and nerves to the bicuspid and incisor teeth. The *inner* or **nasal surface** (facies nasalis) of the body is directed inwards towards the nasal fossæ. Below it is confluent with the upper

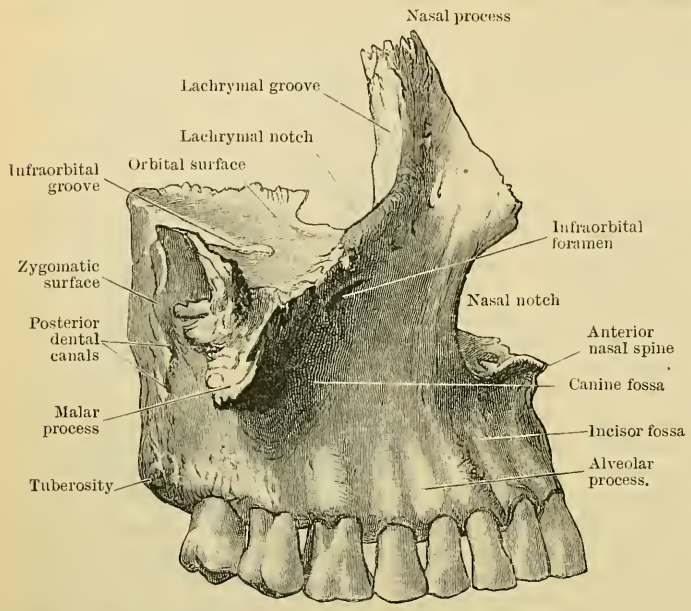


FIG. 103.—RIGHT SUPERIOR MAXILLA (Outer View).

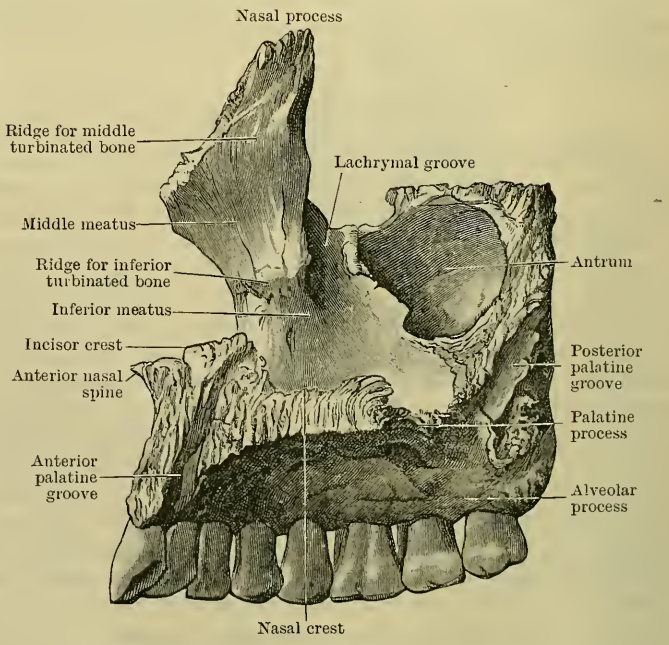


FIG. 104.—RIGHT SUPERIOR MAXILLA (Inner Aspect).

surface of the palatal process; in front it is limited by the sharp edge of the nasal notch; above and in front it is continuous with the inner surface of the frontal process; behind this it is deeply channelled by the **lachrymal groove**, which is converted into a canal by articulation with the lachrymal and inferior turbinated bones. The channel so formed conveys the nasal duct from the orbital cavity above to the inferior nasal meatus below. Behind this groove the upper edge of this area corresponds to the inner margin of the orbital surface, and articulates from before backwards with the lachrymal, os planum of the ethmoid, and the orbital process of the palate bone. The posterior border, rough for articulation with the palate bone, is traversed obliquely from above downwards and slightly inwards by a groove, which, by articulation with the palate bone, is converted into the **posterior palatine** or **palato-maxillary canal** which transmits the descending palatine artery and great palatine nerve. Towards its upper and hinder part the nasal surface of the body displays the irregular, more or less triangular, opening of the **antrum** (sinus maxillaris). This aperture, which, in the articulated skull opens into the middle meatus of the nose, is much reduced in size by articulation with the lachrymal, ethmoid, palate, and inferior turbinal bones. In front of the lachrymal groove the inner surface is ridged horizontally by the **inferior turbinated crest** (crista conchalis), to which the inferior turbinated bone is attached. Below this the bone forms the outer wall of the inferior nasal meatus, receiving the termination of the lachrymal groove. Above, and for some little distance also on the inner side of the frontal process, it constitutes the smooth outer wall of the **atrium** of the middle meatus.

The **zygomatic or malar process** (processus zygomaticus), which is placed on the outer surface of the body, is confluent anteriorly with the facial surface of the body; posteriorly, where it is concave from side to side, with the zygomatic surface; whilst superiorly, where it is rough and articular, it forms the apex of the triangular orbital plate, and supports the malar bone. Inferiorly, its anterior and posterior surfaces meet to form an arched border, which fuses with the alveolar process opposite the root of the first molar tooth, and serves to separate the facial from the zygomatic aspects of the body.

The **frontal or nasal process** (processus frontalis) rises from the upper and fore-part of the body. It has two surfaces—one external, the other internal. The *external* is divided into two by a vertical ridge (crista lachrymalis anterior), which is the upward extension of the infraorbital margin. The narrow strip of bone behind this ridge is hollowed out, and leads into the lachrymal groove below. Posteriorly the edge of the frontal process here articulates with the lachrymal, and so forms the fossa for the lodgment of the lachrymal sac (fossa sacci lacrimalis). In front of the vertical crest, to which the tendo oculi is attached, the external surface is confluent below with the facial aspect of the body, and forms the side of the root of the nose. Its anterior edge is rough, or grooved, for articulation with the nasal bone. Superiorly the summit of the process is serrated for articulation with the nasal notch of the frontal bone. The *inner surface* of the nasal process is directed towards the nasal fossæ. It is crossed obliquely from below upwards and backwards by a ridge—the **agger nasi** or **superior turbinated crest** (crista ethmoidalis). Below this the bone is smooth and forms the upper part of the atrium, whilst the ridge itself articulates posteriorly with the fore-part of the middle turbinated bone, formed by the inferior turbinated process of the ethmoid bone.

The **alveolar process** (processus alveolaris) projects from the under surface of the body of the bone below the level of the palatal process. Of curved form, it completes, with its fellow of the opposite side, the alveolar arch, in which are embedded in sockets or alveoli the roots of the teeth of the upper jaw; ordinarily in the adult, when dentition is complete, each alveolar process supports eight teeth. Piercing the inner surface of the alveolar border behind the incisor teeth two small vascular foramina are usually visible. When any or all the teeth are shed the alveoli become absorbed, and the process may under these circumstances be reduced to the level of the plane of the palatal process. Posteriorly the alveolar process ends below the **tuberosity** of the body; anteriorly it shares in the formation of the **intermaxillary suture**.

The **palatal process** (processus palatinus), of the form of a quadrant, lies in the horizontal plane; it has two surfaces—upper and under—and three borders, a straight internal, a more or less straight posterior, and a curved external, by which latter it is attached to the inner side of the body and alveolar process as far back as the interval between the second and third molar teeth. Its *under surface*, together with that of its fellow, forms the anterior three-fourths of the vaulted hard palate; it is rough and pitted for the glands of the mucous membrane of the roof of the mouth, and is grooved on either side near the alveolar margin by a channel which passes forward from the **posterior palatine canal** and transmits the great palatine nerve and descending palatine artery. Its *superior surface*, smooth and concave from side to side, forms the floor of the corresponding nasal fossa. Its *internal* or *mesial border*, broad and serrated, rises in a ridge superiorly, so as to form with its fellow of the opposite side the **nasal crest** (crista nasalis), which is grooved superiorly to receive the lower border of the vomer. In front of its articulation with the vomer this ridge rises somewhat higher, being named the **incisor crest**, anterior to which it projects beyond the free border of the nasal notch, and together with its fellow forms the pointed projection called the **anterior nasal spine** (spina nasalis anterior). These parts support the septal cartilage of the nose. Immediately to the outer side of the incisor crest the superior surface of the palatal process is pierced by a foramen which leads downwards, forward, and a little inwards, to open into a broad groove on the mesial border of the bone immediately behind the central incisor tooth. When the two maxillæ are articulated, the two grooves form the oval **anterior palatine canal** or **fossa**, into which the two aforementioned foramina open like the limbs of a Y; these are called the **incisor foramina**, or the **foramina of Stensen**, and contain the remains of the organs of Jacobson. In front and behind these, and lying within the fossa and in *the line* of the suture, are the smaller **foramina of Scarpa**, which transmit the naso-palatine nerves, the right nerve usually passing through the posterior foramen, the left through the anterior. The *posterior border* of the palatal process, which is sharp and thin, falls in line with the interval between the second and third molar, and articulates with the horizontal plate of the palate bone.

The **maxillary sinus** or **antrum of Highmore** (sinus maxillaris) lies within the body of the bone, and is of corresponding pyramidal form, its base being directed towards the nasal fossa, with the middle meatus of which it communicates, its summit extending outwards into the root of the zygomatic process. It is closed in externally and above by the thin walls which form the facial, zygomatic, and orbital surfaces of the body. Inferiorly it overlies the alveolar process in which the molar teeth are implanted, the sockets of which are separated from it by a thin layer of bone.

Advantage is taken of this circumstance to pierce the floor of the antrum in such conditions as necessitate its thorough drainage, as its natural outlet into the middle meatus is of the nature of an overflow aperture, and so prevents purulent fluids, which may here accumulate, from being readily discharged.

The angles and corners of this cavity are frequently groined by narrow ridges of bone, one superiorly corresponds to the relief formed by the infraorbital canal. A vascular and nervous groove is often exposed, curving along the floor of the antrum just above the alveoli of the teeth. The interior of the cavity is lined by an extension from the mucous membrane of the nose.

Connexions.—The superior maxillary bone articulates with the nasal, frontal, lachrymal, and ethmoid bones above, externally with the malar, and occasionally with the sphenoid, posteriorly and internally with the palate, whilst on its inner side it unites with its fellow of the opposite side, and also supports the inferior turbinated bone and the vomer.

Architecture.—The disposition of the maxillary sinus within the body of the bone has been already referred to. In union with its fellow, the vaulted arrangement of the hard palate is well displayed, and the arched arrangement of the superior alveolar processes is obvious. It is in these latter processes around the sockets for the reception of the teeth that the cancellous tissue of the bone is seen; elsewhere its walls are formed by thin and dense bone.

Variations.—Not unfrequently there is a suture running vertically through the bar of bone which separates the infraorbital foramen from the infraorbital margin. Through imperfections in ossification the infraorbital canal may form an open groove along the floor of the orbit.

Ossification.—The superior maxillæ are developed in the connective tissue around the oral aperture of the embryo. The centres from which the bone ossifies are not preceded by a cartilaginous stage. Their number is uncertain, as early fusion occurs between them. They first make their appearance in the second month of intrauterine life, shortly after the clavicle has begun to ossify. By the sixth month they are so united that their independent character is obscured. Five centres are described—an *external* or *malar*, which forms the bone to the outer side of the infraorbital canal; an *inner* or *orbito-nasal*, from which is developed the inner part of the floor of the orbit, the frontal process, and the wall of the antrum; a *palatine*, for the posterior three-fourths of the palatal process; a *nasal*, situated between the frontal process and the canine tooth; and within this and nearer the middle line and below, an *incisive centre*, from which the premaxillæ are developed, thus forming the anterior fourth of the palatal process in the adult. In the early stages of the development of the bone the alveolar groove, in which the teeth are developed, lies close below the infraorbital groove, and it is not till later that they become separated by the growth of the antrum, which first makes its appearance as a shallow fossa to the inner side of the orbito-nasal element about the fourth month. In the adult bone the course of the infraorbital canal and foramen indicates the line of fusion of the orbito-nasal and malar elements, whilst the position of the anterior palatine canal serves to determine the line of union of the incisive with the palatal elements. In addition to the foregoing centres, Rambaud and Renault describe another which, together with its fellow, is wedged in between the incisive and the palatal elements beneath the vomer, thus explaining the Y-shaped arrangement of the foramina of Stensen, which open into the anterior palatine canal.

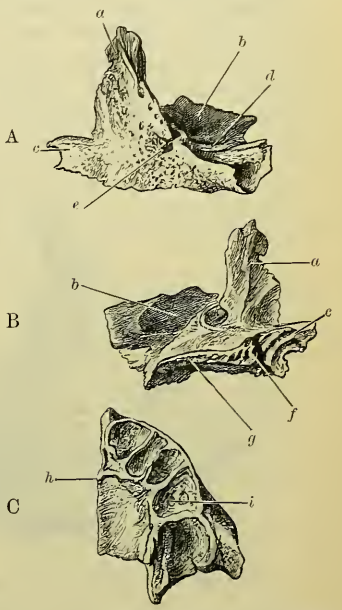


Fig. 105.—Ossification of Superior Maxilla.

A, Outer side; B, Inner side; C, Under side. *a*, Nasal process; *b*, Orbital plate; *c*, Anterior nasal spine; *d*, Infraorbital groove; *e*, Infraorbital foramen; *f*, Anterior palatine groove; *g*, Palatal process; *h*, Premaxillary suture; *i*, Alveolar process.

The **premaxillæ**, which in most vertebrates are independent bones lying in front of the superior maxillæ, constitute in man and apes the portions of the upper jaw which lie in front of the anterior palatine foramen, and support the superior incisor teeth. They are developed from the incisive centres above described; the line of fusion of these elements with the maxillæ proper can readily be seen in young skulls, and occasionally also in the adult. It corresponds to a suture which passes on the palate obliquely outwards and forwards, from the anterior palatine foramen to the interval between the lateral incisor and the canine tooth. In cases of alveolar cleft palate the adjacent bones fail to unite along the line of the suture. In some instances, however, the cleft passes outwards between the central and lateral incisor teeth, and this condition suggests the explanation that the premaxillary element is derived from two centres—a lateral and a mesial. The researches of Albrecht and Warinski have confirmed this view. The latter anatomist further observes that the lateral cleavage may lead to a division of the dental germ of the lateral incisor tooth, and so explain the occurrence of the supernumerary incisor which is occasionally met with. In this way the different varieties of cleft palate are readily explained; mesial cleft palate being due to failure of union between the two premaxillary bones. Lateral cleft palate may be of two types: the cleft in one case passing forward between the central and lateral incisor, and being due to the non-union of the two elements from which the premaxilla is primarily developed; the other, in which the cleft passes between the lateral incisor and the canine, or between the lateral incisor and a supernumerary incisor, owing to the imperfect fusion of the premaxilla laterally with the maxilla.

The Malar Bones.

The **malar bone** (os zygomaticum) underlies the most prominent part of the cheek, and is hence often called the cheek-bone. Placed to the outer side of the orbital cavity, it forms the sharp external border of that hollow, and serves to

separate that space from the temporal and zygomatic fossæ which lie behind; below, it rests upon and is united to the superior maxilla; behind, it enters into the formation of the zygomatic arch which bridges across the temporal fossa.

As viewed from the outer side, the bone is convex from side to side, and has four angles, of which three are prominent. These are the **ascending** or **frontal** (processus fronto-sphenoidalis), the **anterior** or pointed extremity of the maxillary border, and the **posterior** or **temporal** (processus temporalis).

The most elevated part of the convex *outer surface* (facies anterior) forms the **malar tuberosity.** The **processus temporalis**, sometimes called the zygomatic process, ends posteriorly in an oblique edge, which articulates with the extremity of the zygomatic process of the temporal bone. The **frontal**, the most prominent of its processes, is united superiorly to the external angular process of the frontal bone. The edge between the frontal and temporal processes is thin and sharp; it affords attachment to the temporal fascia, and near its upper end there is usually a pronounced angle (processus marginalis), formed by a sudden change in the direction of the border of the bone. It is just below this point that the temporal branch of the orbital nerve becomes cutaneous. The lower margin of the temporal process is somewhat thicker and rounded; it extends downwards and forwards towards the inferior angle, where the bone articulates with the superior maxilla,

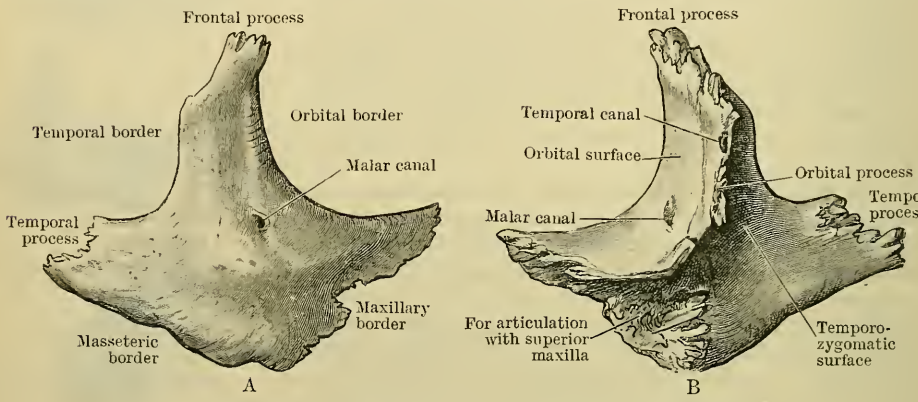


Fig. 106.—Right Malar Bone. A, Outer Side; B, Inner Side.

and is there confluent with the ridge which separates the facial from the zygomatic aspect of the upper jaw. This edge of the bone is sometimes called the **masseteric border,** since it affords attachment to the fibres of origin of the masseter muscle. Sweeping downwards in front of the frontal process is a curved edge which terminates inferiorly in a pointed process. This border forms the outer and, in part, the inferior margin of the orbital cavity. Between the anterior extremity of the masseteric edge and the pointed anterior angle there is an irregular suture by which the bone is joined to the maxilla. The opening of the **malar canal** (foramen zygomatico-faciale) is seen on the outer surface of the bone; its size and position are very variable.

The *mesial aspect* of the bone is distinguished by a curved elevated crest, called the **orbital process,** which extends inwards and backwards, and is confluent externally with the orbital margin. This process has two surfaces—one anterior, which forms a part of the outer and lower wall of the orbit, and one posterior, which is directed towards the temporal fossa above and the zygomatic fossa below. The free edge of the orbital process is thin and serrated; a little below its middle it is usually interrupted by a non-articular notch, which corresponds to the anterior extremity of the spheno-maxillary fissure. The part above this articulates with the great wing of the sphenoid, the portion below with the orbital plate of the superior maxilla. Behind the orbital process the inner surface of the bone is concave from side to side, and extends backwards along the mesial aspect of the temporal process and upwards over the posterior half of the inner side of the frontal process, thus entering into the formation of the zygomatic and temporal fossæ respectively.

The orbital surface of the orbital process usually displays the openings of two **canals** (foramina zygomatic-orbitalia)—one which traverses the bone below the orbital margin and appears on the front of the bone as already described, the other which passes obliquely upwards and outwards through the orbital process and appears in the temporal fossa, to the inner side of the frontal process (foramen zygomatico-temporale). The former transmits the ramus subcutaneous malæ; the latter the temporal branch of the orbital nerve.

Below the orbital process there is a rough triangular area, bounded externally by the maxillary border. This articulates with the malar process of the superior maxilla, and occasionally forms the outer wall of the antrum.

Connexions.—The malar bone articulates with the frontal, sphenoid, superior maxilla, and temporal bones.

Architecture.—In structure the bone is compact, with little cancellous tissue. Together with the zygomatic process of the temporal bone it forms the buttress which supports the superior maxilla and the outer orbital wall externally. Additional strength is imparted to the bone by the angular mode of union of its orbital and facial parts.

Variations.—Cases of division of the malar bone by a horizontal suture have been recorded, as well as instances of its separation into two parts by a vertical suture. Owing to the supposed more frequent occurrence of this divided condition in Asiatics the malar has been named the os Japonicum. Barclay Smith ("Proc. Anat. Soc.," *Jour. Anat. and Physiol.*, April 1898, p. 40) describes a case in which the malar bone was divided into two parts, an upper and lower, by a backward extension of the maxilla, which articulated with the zygomatic process of the temporal, thus forming a temporo-maxillary arch. Varieties of a like kind have also been described by Gruber and others. Cases have been noted where, owing to deficiency in the development of the malar, the continuity of the zygomatic arch has been incomplete.

Ossification.—The malar ossifies in membrane. Its basis appears about the tenth week as a thin ossifying lamina which corresponds to the orbital margin, attached to which there is a backward expansion corresponding to the body of the bone; from this posteriorly there extends the element of the temporal process. On the inner side, and above the angle formed by the orbital and temporal margins, there appears a secondary thickening, which develops into a cap-shaped layer which fits into the recess and ultimately forms the surface of the bone directed to the temporal fossa. Below the orbital margin on the inner side, and extending backwards towards the temporal process, is another secondary thickening which forms a club-shaped nodule, the thick end of which is directed forwards, whilst posteriorly it forms, in part, the lower margin of the body and temporal process. The overlap of these several parts leads to the formation of grooves which may persist in the adult as sutures. (Karl Toldt, junr., *Sitzsbr. des Akad. des Wiss.*, Wien. July 1902.)

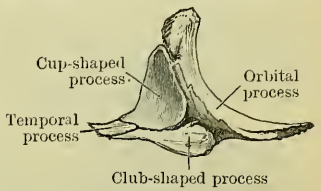


FIG. 107.—INNER SURFACE OF MALAR BONE AT BIRTH.

THE NASAL BONES.

The **nasal bones** (ossa nasalia), two in number, lie in the interval between the frontal processes of the superior maxillæ, there forming the root or bridge of the nose. Each bone is of elongated quadrangular form, having two surfaces—an inner and outer—and four borders. The *external surface*, somewhat constricted about its middle, is convex from side to side, and slightly concavo-convex from above downwards. Near its centre there is usually the opening of a nutrient canal.

The *internal surface* is not so extensive as the external, as the superior and anterior articular borders encroach somewhat upon it above. Concave from side to side, and also from above downwards, it is covered, in the recent condition, by the mucous membrane of the nose. Running downwards along this surface is a narrow groove (sulcus ethmoidalis) which transmits the internal nasal nerve. The *anterior* or *internal border*, narrow below, is thick above, and, in conjunction with its fellow at the opposite side, with which it articulates, forms a median crest posteriorly, which is united to the nasal spine of the frontal, the vertical plate of the ethmoid, and the septal cartilage of the nose, in that order from above downwards. The *posterior* or *external border*, usually the longest, is serrated and

bevelled to fit on to the anterior edge of the frontal process of the superior maxilla. The *superior border* forms a wide toothed surface, which articulates with the inner part of the nasal notch of the frontal bone anteriorly; whilst, behind, it rests in contact with the root of the nasal process of the same bone. The *inferior border* is thin and sharp, and is connected below with the lateral cartilage of the nose, and is usually deeply notched near its mesial extremity.

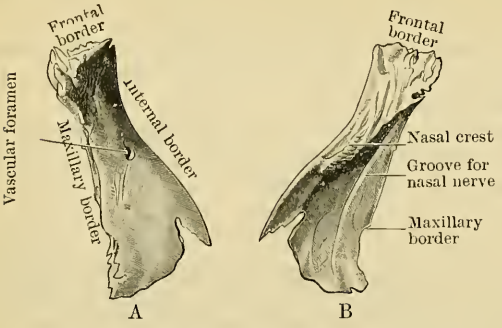


FIG. 108.—RIGHT NASAL BONE. A, Outer side; B, Inner side.

Connexions.—The nasal bone articulates with its fellow of the opposite side, with the frontal above, behind with the mesial plate of the ethmoid and with the frontal process of the superior maxilla. It is also united to the septal and upper lateral cartilages of the nose.

Architecture.—Formed of dense and compact bone; the strength of the nasal bones is increased by their mode of union and the formation of a median crest posteriorly.

Variations.—The size and configuration of the nasal bones vary greatly in different races, being, as a rule, large and prominent in the white races, and flat and reduced in size, as well as depressed, in the Mongolian and Negro stock. Obliteration of the internasal suture is unusual; it is stated to occur more frequently in negroes, and is the recognised condition in adult apes.

Duckworth has recorded a case (*Journ. Anat. and Physiol.*, vol. xxxvi. p. 257) of undue extension downwards of the nasal bone, which may be perhaps accounted for on the supposition that the lower part is a persistent portion of the premaxilla.

Ossification.—The nasal bones are each developed from a single centre, which makes its appearance about the end of the second month in the membrane covering the fore-part of the cartilaginous nasal capsule. Subsequent to birth the underlying cartilaginous stratum disappears, persisting, however, below in the form of the lateral nasal cartilage, and behind as the septal cartilage of the nose.

THE LACHRYMAL BONES.

The **lachrymal bone** (os lachrymale), or os unguis, a thin scale of bone about the size of a finger-nail, forms part of the inner orbital wall behind the frontal process of the superior maxilla. Irregularly quadrangular, it has two surfaces—an inner and outer—and four borders.

Its *external* or *orbital surface* has a vertical ridge, the **lachrymal crest** (crista lachrymalis posterior), running downwards upon it. In front of this is the **lachrymal groove** (sulcus lachrymalis) for the lodgment of the lachrymal sac. The floor of this groove descends below the level of the bulk of the bone, and forms the **descending process**, which helps to complete the osseous canal for the nasal duct, and articulates inferiorly with the inferior turbinal. The lower end of the lachrymal crest terminates in a hook-like projection, the **hamular process** (hamulus lachrymalis), which curves round the posterior and outer edge of the lachrymal notch of the superior maxilla, and thus defines the upper aperture of the canal for the nasal duct. To the free edge of the crest behind the lachrymal groove are attached the reflected portion of the tendo oculi, and the tensor tarsi muscle. The part of the bone behind the lachrymal crest is smooth and continuous with the surface of the os planum of the ethmoid. The *inner surface* is irregular and cellular above; it closes in some of the anterior ethmoidal cells. Where it is smoother it forms a part of the lateral wall of the middle meatus of the nose immediately behind the frontal process of the superior maxilla, and above the inferior turbinated bone. The *superior border* articulates with the orbital plate of the frontal; the *anterior edge* with the posterior border of the frontal process of the superior maxilla, with

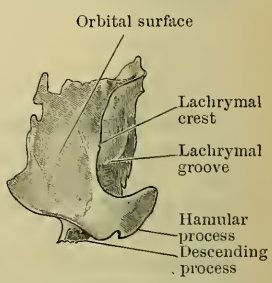


FIG. 109.—RIGHT LACHRYMAL BONE (Orbital Surface).

which it completes the lachrymal groove for the lodgment of the lachrymal sac. The *inferior margin* articulates with the orbital surface of the superior maxilla, and in front by its **descending process** with the inferior turbinal. *Posteriorly* the bone articulates with the anterior border of the os planum of the ethmoid.

Connexions.—The lachrymal bone articulates with four bones—the frontal, ethmoid, inferior turbinal, and the superior maxilla.

Architecture.—The bone consists of a thin papery translucent lamina, somewhat strengthened by the addition of the vertical crest.

Variations.—The lachrymal is occasionally absent. In some cases it is divided into two parts; in others replaced by a number of smaller ossicles. In rare instances the hamular process may extend forwards to reach the orbital margin, and so bear a share in the formation of the face, as in lemurs (Gegenbauer). In other instances the hamulus is much reduced in size. Occasionally the lachrymal is separated from the os planum of the ethmoid by a down-growth from the frontal, which articulates with the orbital process of the superior maxilla, as is the normal disposition in the gorilla and chimpanzee. (Turner, *Challenger Reports*, "Zoology," vol. x. Part IV. Plate I.; and A. Thomson, *Journ. Anat. and Physiol.*, London, vol. xxiv. p. 349.)

Ossification.—The lachrymal is developed from a single centre, which makes its appearance about the end of the second or the beginning of the third month of intra-uterine life in the membrane around the cartilaginous nasal capsule.

The Inferior Turbinated Bones.

The **inferior turbinated** or spongy bone (concha inferior) is a shell-like lamina of bone lying along the lower part of the outer wall of the nasal fossa. Of elongated form, the bone displays two curved borders enclosing an internal and external surface.

The *superior* or *attached* border is thin and sharp in front and behind, where

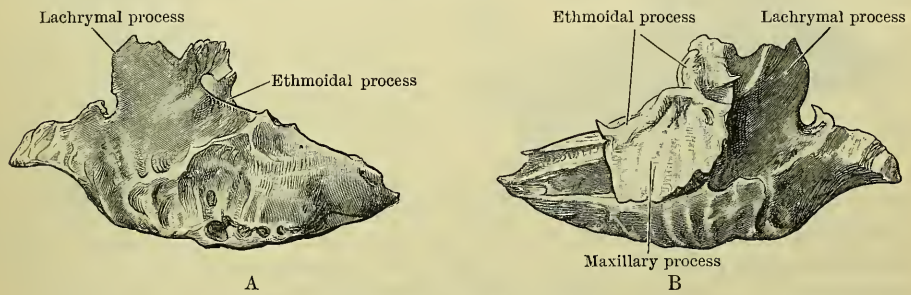


Fig. 110.—Right Inferior Turbinated Bone. A, Inner Surface; B, Outer Surface.

it articulates with the inferior turbinal crests on the inner surface of the body of the superior maxilla and the vertical plate of the palate bone respectively. Between these two borders the central part of the upper edge rises in the form of a sharp crest, the fore-part of which forms the upstanding **lachrymal process** (processus lachrymalis), which articulates above with the descending process of the lachrymal bone, as well as with the edges of the nasal groove of the superior maxilla, thus completing the osseous canal of the nasal duct. The posterior end of this crest is elevated in the form of an irregular projection called the **ethmoidal process** (processus ethmoidalis). This unites with the uncinate process of the ethmoid bone (see Fig. 101). Spreading downwards from the middle of the superior border, on its outer side, is a thin, irregular plate of bone, the **maxillary process** (processus maxillaris), which partially conceals the outer concave surface of the bone, and, by its union with the inner wall of the maxillary sinus, assists in the completion of the partition which separates that cavity from the inferior nasal meatus. The *inferior* or *free border*, gently curved from before backwards and slightly out-turned, is rounded and full, and formed of bone which is deeply pitted and of a somewhat cellular character. The anterior and posterior extremities of the bone, formed by the convergence of the upper and lower borders, are thin and sharp; as a rule the hinder end is the more pointed of the two. The *internal surface* projects into the nasal fossa; convex from above downwards, and slightly

curved from before backwards, it forms the floor of the middle meatus. It is rough and pitted, and displays some scattered and longitudinally directed vascular grooves. The *outer surface* overhangs the inferior nasal meatus. Concave from above downwards, and to some extent from before backwards, it is directed towards the outer wall of the nasal fossa. It is smooth in front, where it corresponds to the opening of the canal for the nasal duct; behind and towards its lower border it is irregular and pitted. In the disarticulated bone this surface is in part concealed by the downward projecting maxillary process.

Connexions.—The inferior turbinal articulates with the superior maxilla, lachrymal, ethmoid, and palate bones.

Variation.—A case in which the inferior turbinals were absent has been recorded by Hyrtl.

Ossification.—The inferior turbinate bone, the maxillo-turbinal of comparative anatomy, is derived from the cartilage forming the outer wall of the nasal capsule, the upper portion of which forms the ethmo-turbinals. It ossifies, however, from a separate centre, which appears about the fifth month of fœtal life, and later contracts a union by a horizontal lamella on its outer side with the superior maxillary bone.

The Vomer.

The **vomer**, a bone of irregular quadrilateral shape, is placed mesially in the hinder part of the nasal septum. It has four borders and two surfaces. The *superior border*, which can readily be distinguished by the presence on either side of an everted lip or ala, slopes from behind upwards and forwards, and articulates with the under surface of the body of the sphenoid, the pointed rostrum of which is received into the groove formed by the projecting alæ. Laterally these **alæ** are wedged in between the sphenoidal processes of the palate bone in front, and the vaginal processes at the root of the internal pterygoid plates behind. The *posterior border*, which slopes from behind downwards and forwards, is free, and forms a sharp, slightly curved edge; this constitutes the posterior margin of the nasal septum, and serves to separate the openings of the posterior nares. The *inferior border*, more or less horizontal in direction, articulates with the nasal crest formed by the superior maxillary and palate bones. The *anterior edge* is the longest; it slopes obliquely from above downwards and forwards. In its upper half it is ankylosed to the perpendicular plate of the ethmoid; in its lower half this margin is grooved for the reception of the septal cartilage of the nose. The *anterior extremity* of the bone forms a truncated angle, which articulates with the hinder border of the incisor crest of the superior maxillæ, and sends downwards a pointed process which passes between the incisor foramina. The *right* and *left surfaces* of the bone are smooth, and covered by mucous membrane. It is not uncommon to find them deflected to one or other side. A few vascular grooves may be noticed scattered over these surfaces, and one, usually more distinct than the others, running obliquely downwards and forwards, indicates the course of the naso-palatine nerve.

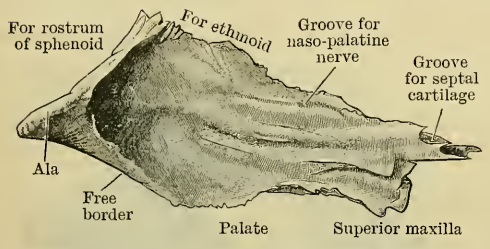


Fig. 111.—Vomer as seen from the Right Side.

Connexions.—The vomer articulates with the sphenoid, the ethmoid, the palates, and the superior maxillæ. In front it supports the septal cartilage.

Architecture.—The bone is composed of two compact layers fused below, but separated above by the groove for the lodgment of the rostrum of the sphenoid behind, and the septal cartilage in front. The lamellæ are also separated from each other by a canal which runs horizontally from behind forwards in the substance of the bone, and which transmits the nutrient vessel of the bone.

Variations.—Owing to imperfect ossification there may be a deficiency in the bone, filled up during life by cartilage. The separation of the two lamellæ along the anterior border varies considerably, and instances are recorded where they were separated by a considerable cavity within the substance of the bone. The spheno-vomerine canal is a minute opening behind

the rostrum of the sphenoid, and between it and the alæ of the vomer, by which the nutrient artery enters the bone.

Ossification.—The vomer, primitively double, begins to ossify about the end of the second month of fœtal life. A nucleus appears on either side in the membrane overlying the back and lower part of the vomerine cartilage; these form the primitive lamellæ developed on either side of, and not from, the cartilage. About the third month these laminæ become fused behind and below, thus forming a deep groove in which the cartilage is lodged. As growth goes on the groove becomes reduced by the further fusion of the lateral plates and the absorption of the cartilage, until the age of puberty, by which time the lateral laminæ have united to form a mesial plate, the primitively divided condition of which is now only represented by the eversion of the alæ and the grooving along the anterior border.

The Palate Bones.

The **palate bone** (os palatinum), of irregular shape, assists in the formation of the outer wall of the back part of the nasal fossæ, the posterior portion of the hard palate, the orbit, the spheno-maxillary, zygomatic, and the pterygoid fossæ. It

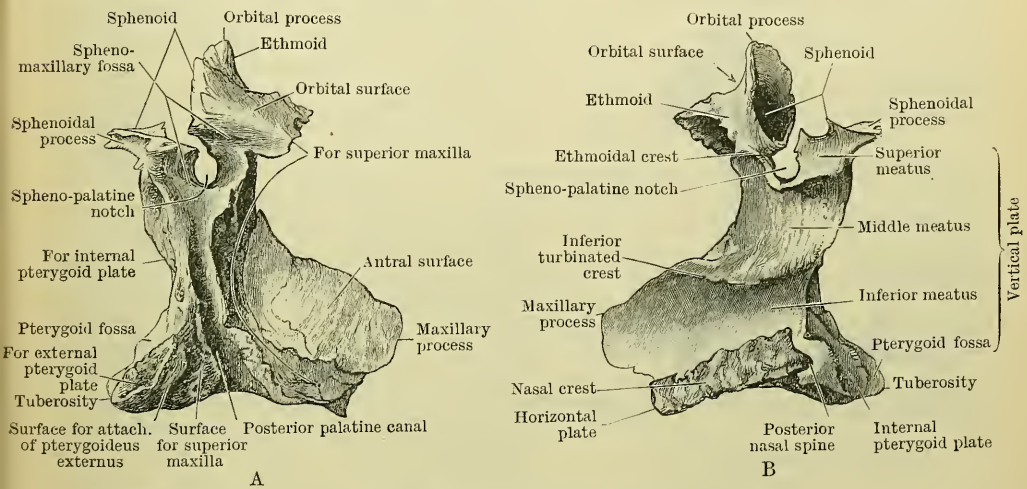


Fig. 112.—Right Palate Bone.

A, As seen from the Outer Side; B, As viewed from the Inner Side.

consists of a **horizontal** and a **vertical plate**, united to each other like the limbs of the letter L. At their point of union there is an irregular outstanding process, called the **tuberosity**, whilst capping the summit of the vertical plate and separated by a deep cleft are two irregular pieces of bone, called the **sphenoidal** and **orbital processes.**

The **horizontal plate** (pars horizontalis) has two surfaces and four borders. As its name implies, it is horizontal in position, and forms the posterior third of the hard palate. Its *upper surface*, which is smooth, is slightly concave from side to side, and forms the floor of the hinder part of the nasal fossæ. Its *inferior surface*, rougher, is directed towards the mouth, and near its posterior edge often displays a transverse ridge for the attachment of a part of the aponeurosis of the tensor palati muscle. The *anterior border* articulates by means of an irregular suture with the hinder edge of the palatal process of the superior maxilla. The *posterior margin* is free and concave from side to side; by its sharp edge it furnishes attachment to the aponeurosis of the soft palate. The *internal border* is upturned, and when it articulates with its fellow of the opposite side it forms superiorly a central crest continuous in front with the nasal crest of the superior maxilla; it supports the hinder part of the lower border of the vomer, and projecting beyond the line of the posterior border forms the **posterior nasal** or **palatine spine** (spina nasalis posterior). The *external border* fuses with the vertical plate, forming with

it a right angle. The hinder extremity of this edge is grooved by the lower end of the **posterior palatine canal.**

The **vertical plate** (pars perpendicularis) is very much broader below than above. Composed of thin bone, it is liable to be broken in the process of disarticulation, particularly at its upper part, so that it is somewhat uncommon to meet with a perfect specimen. It may be described as possessing two surfaces and four borders. Its *inner surface,* which is directed towards the cavity of the nose, is crossed horizontally about its middle by the **inferior turbinated crest** (crista turbinalis) with which the hinder end of the superior border of the inferior turbinated bone articulates; above and below this it enters into the formation of the outer wall of the middle and inferior meatuses of the nose respectively. Near the upper extremity of the vertical plate, and below the processes which spring from it, there is another ridge more or less parallel to that already described. This is the **superior turbinated** or **ethmoidal crest** (crista ethmoidalis), and with this the hinder extremity of the middle turbinated bone is united. The *external surface,* which forms the inner wall of the spheno-maxillary fossa, is channelled by a vertical groove (sulcus pterygo-palatinus), converted into a canal by articulation with the superior maxillary bone. This canal, called the **posterior palatine canal** transmits the large palatine nerve and descending palatine vessels. Anteriorly the external surface projects forwards to a variable extent, and helps to close in the antrum of the maxilla by its **maxillary process.** The *anterior border* is a thin edge of irregular outline which articulates above with the ethmoid, with the posterior edge of the maxillary process of the inferior turbinated bone about its middle, and below with the superior maxilla. The *posterior border,* thin above, where it articulates with the fore-part of the internal pterygoid plate, expands below into a pyramidal process called the **tuberosity.** The *inferior border* of the vertical plate is confluent with the outer edge of the horizontal plate; posteriorly, and immediately in front of the tuberosity, it is notched by the lower extremity of the posterior palatine canal. The *superior border* supports the **orbital** and **sphenoidal processes**; the former—the anterior—is separated from the latter by a **notch** (incisura spheno-palatina), which is converted into the **spheno-palatine foramen** by the articulation of the palate bone with the under surface of the sphenoid. Through this communication between the spheno-maxillary and nasal fossæ pass the spheno-palatine artery and the nasal branches of the spheno-palatine ganglion.

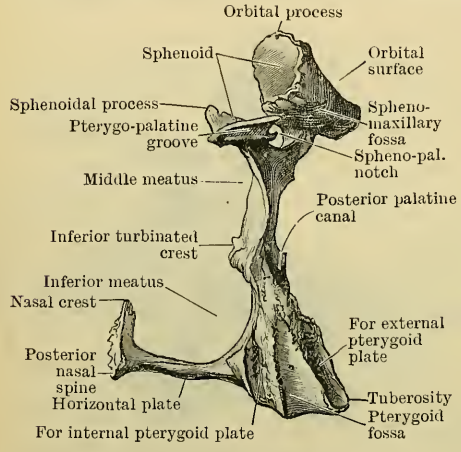


FIG. 113.—RIGHT PALATE BONE.
As seen from Behind.

The **tuberosity** (processus pyramidalis) is directed backwards and outwards from the angle formed by the vertical and horizontal plates, and presents on its *posterior surface* a central smooth vertical groove, bounded on either side by rough articular furrows which unite above in a V-shaped manner with the upper thin posterior edge. These latter articulate with the fore-parts of the lower portions of the internal and external pterygoid plates, while the central groove fits into the wedge-like interval between the two pterygoid plates, thus entering into the formation of the pterygoid fossa. The *outer surface* of the tuberosity is rough above, where it is confluent with the outer surface of the vertical plate which articulates with the tuberosity of the superior maxilla; *below,* there is a small, smooth, triangular area which appears between the tuberosity of the superior maxilla and the outer surface of the external pterygoid plate, and so enters into the floor of the zygomatic fossa. Passing through the tuberosity in a vertical direction are the **posterior** and **external accessory palatine canals** (foramina palatina minora) for the transmission of the smaller palatine nerves and vessels.

The **orbital process** (processus orbitalis), shaped like a hollow cube, surmounts the fore-part of the vertical plate. The open mouth of the cube is usually directed backwards and inwards towards the fore-part of the body of the sphenoid, with the cavity of which it commonly communicates; the fore-part of the cube articulates with the inner end of the angle formed by the orbital plate and zygomatic surface of the superior maxilla. Of the remaining four surfaces, one directed forwards and inwards articulates with the ethmoid. The others are non-articular: the *superior* enters into the formation of the floor of the orbit; the *external* is directed towards the spheno-maxillary fossa; whilst the *inferior*, which is confluent with the inner surface of the vertical plate, is of variable extent, and overhangs the superior meatus of the nose.

The **sphenoidal process** (processus sphenoidalis), much smaller than the orbital, curves upwards, inwards, and backwards from the hinder part of the summit of the vertical plate. Its superior surface, which is grooved, articulates with the fore-part of the under surface of the body of the sphenoid and the root of the internal pterygoid plate, thereby converting the groove into the **pterygo-palatine canal**, which transmits an artery of the same name together with a pharyngeal branch from the spheno-palatine ganglion. Its outer side enters into the formation of part of the inner wall of the spheno-maxillary fossa. Its internal curved aspect is directed towards the nasal fossa, whilst its inner edge is in contact with the ala of the vomer.

Connexions.—The palate bone articulates with its fellow of the opposite side, with the ethmoid, vomer, sphenoid, superior maxilla, and inferior turbinated bones.

Ossification.—The palate bones are developed from the ossification of the membrane covering the sides of the oral cavity. According to Rambaud and Renault, two primitive centres appear about the sixth week of fœtal life. From one of these the tuberosity and the part of the vertical plate behind the posterior palatine groove is developed; from the other the remainder of the bone is formed, with the exception of the orbital and sphenoidal processes which are derived from secondary centres that make their appearance somewhat later. Other authorities describe the bone as ossifying from a single centre which appears about the end of the second month in the angle between the vertical and horizontal plates.

At birth the bone is much longer in its antero-posterior diameter than in its vertical height, the converse of its typical adult form.

The Inferior Maxillary Bone.

The **inferior maxilla** (mandibula) or **mandible**, of horse-shoe shape, with the extremities upturned, is the only movable bone of the face. Stout and strong, it supports the teeth of the lower dental arch, and articulates with the base of the cranium, by the joints, on either side, between its condyles and the glenoid fossæ of the temporal bones. The anterior or horizontal part, which contains the teeth, is called the **body** (corpus); the posterior or vertical portions constitute the **rami** (rami mandibulæ).

The **body** (corpus mandibulæ) displays in the middle line in front a faint vertical ridge, the **symphysis**, which indicates the line of fusion of the two symmetrical halves from which the bone is primarily developed. Inferiorly this ridge divides so as to enclose, in well-marked specimens, a triangular area—the **mental protuberance** (protuberantia mentalis), the centre of which is somewhat depressed, thus emphasising the inferior angles, which are known as the **mental tubercles** (tubera mentalia). The *outer surface* is crossed by a faint, elevated ridge, the **external oblique line** (linea obliqua), which runs upwards and backwards from the mental tubercle to the fore-part of the anterior border of the ramus, with which it is confluent. A little above this, midway between the upper and lower borders of the jaw, and in line with the root of the second bicuspid tooth, the bone is pierced by the **mental foramen** (foramen mentale); this is the anterior opening of the inferior dental canal, which traverses the body of the bone. Through this aperture the mental vessels and nerves reach the surface. The *upper border*

supports the sixteen teeth of the lower jaw. It is thick behind and thinner in front, in correspondence with the size of the roots of the teeth. Anteriorly the sockets of the incisor and canine teeth produce a series of vertical elevations (juga alveolaria), of which that corresponding to the canine tooth is the most prominent. When this is outstanding it gives rise to a hollowing of the surface between it and the symphysis, often referred to as the **incisor fossa**; frequently, however, this is only faintly marked. Below the external oblique line the bone is full and rounded, and ends below in the *inferior border* or **base**. This slopes outwards at the sides, and forwards in front, where it is thick and hollowed out on either side of the symphysis to form the **digastric fossæ** (fossæ digastricæ), to which the anterior bellies of the digastric muscles are attached; narrowing somewhat behind this, the inferior border again expands opposite the molar teeth, and finally becoming reduced in width, terminates posteriorly at the **angle** formed between it and the posterior border of the ramus. The *deep* or *inner surface* of the body is crossed by the **internal oblique line** or **mylo-hyoid ridge** (linea mylo-hyoidea). This slants from above downwards and forwards towards the lower part of the symphysis. It serves for the origin of the mylo-hyoid muscle, and also furnishes an attachment to the superior constrictor of the pharynx just behind the last molar tooth. Below the hinder part of this ridge the surface is hollowed to form a **fossa** for the lodgment of the submaxillary gland. Above the fore-part of the internal oblique line the bone is smooth and usually convex. Here the sublingual gland lies in relation to it. In the angle formed by the convergence of the two internal oblique lines, and in correspondence with the back of the lower part of the symphysis, there is a raised tubercle surmounted by two laterally placed spines, the **mental** or **genial spines** (spinæ mentales). Occasionally these are again subdivided into an upper and lower pair, or it may be that the lower pair may fuse to form a rough median ridge. To the upper pair of spines the genio-hyoglossi muscles are attached, whilst the lower pair serve for the origin of the genio-hyoid muscles. Immediately above the tubercle there is a median foramen for the transmission of a nutrient vessel, and close to the alveolar border opposite the intervals between the central and lateral incisors, there are two little vascular canals.

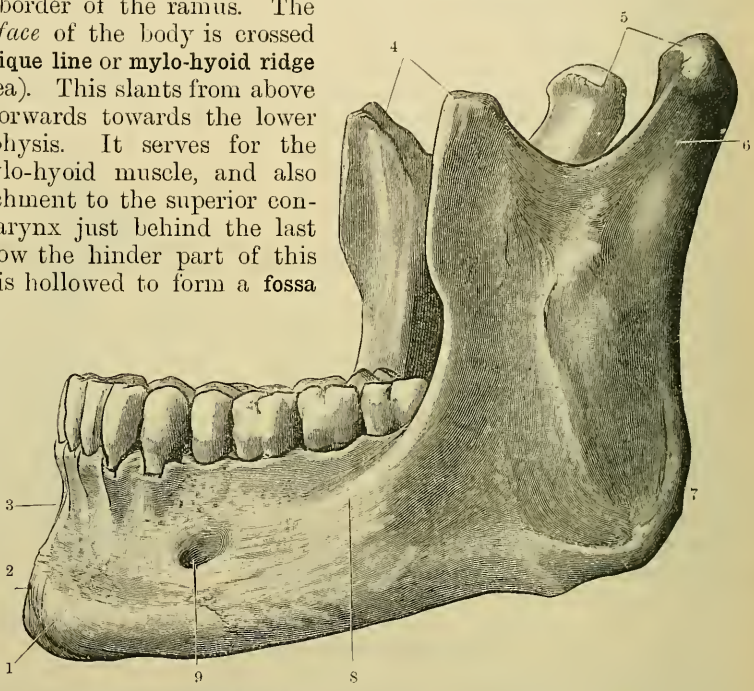


Fig. 114.—The Lower Jaw as seen from the Left Side.

1. Mental tubercle.
2. Mental prominence.
3. Symphysis.
4. Coronoid process.
5. Condyles.
6. Neck.
7. Angle.
8. External oblique line.
9. Mental foramen.

The **ramus** (ramus mandibulæ) passes upwards from the back part of the bone, forming by the junction of its posterior border with the base of the body the **angle** (angulus mandibulæ), which is usually rounded and more or less everted. The outer surface of the ramus affords attachment to the masseter muscle, and when that muscle is powerfully developed the bone is usually marked by a series of oblique curved ridges, best seen towards the angle. About the middle of the deep or inner surface is the large opening (foramen mandibulare) of the **inferior dental**

canal, which runs downwards and forwards to reach the body, and transmits the inferior dental vessels and nerves. This aperture is overhung in front by a pointed scale of bone, the **lingula**, to the edges of which the internal lateral ligament of the temporo-maxillary articulation is attached. Behind the lingula and leading downwards and forwards for an inch or so from the opening of the inferior dental canal is the **mylo-hyoid groove** (sulcus mylo-hyoideus), along which the mylo-hyoid artery and nerve pass. Behind and below this groove the inner surface of the angle is rough for the attachment of the internal pterygoid muscle. Superiorly the ramus supports the **coronoid process** in front, and the **condyle** behind, the two being separated by the wide **sigmoid notch** (incisura mandibulæ), over which there pass in the recent condition the vessels and nerve to the masseter muscle. The **coronoid process**, of variable length and beak-shaped, is limited behind by a thin curved margin, which forms the anterior boundary of the sigmoid notch. In front its anterior edge is convex from above downwards and forwards, and becomes confluent below with the anterior border of the ramus and the external oblique line. To the inner side of this edge there is a grooved elongated triangular surface, the inner margin of which, commencing above near the summit of the coronoid process, leads downwards along the inner side of the root of the last molar tooth towards the internal oblique line. Behind this ridge the thickness of the ramus is much reduced. The temporal muscle is inserted into the margins and inner surface of the coronoid process. The posterior border of the ramus is continued upwards to support the **condyle** (capitulum mandibulæ), below which it is somewhat constricted to form the **neck** (collum mandibulæ), which is compressed from before backwards, and bounds the sigmoid hollow posteriorly. To the inner side of the neck, immediately below the condyle, there is a little depression (fovea pterygoidea) for the insertion of the external pterygoid muscle. The convex surface of the condyle is transversely elongated, and so disposed that its long axis is inclined nearly horizontally from within outwards and a little forwards. The convexity of the condyle is more marked in its antero-posterior than in its transverse diameter.

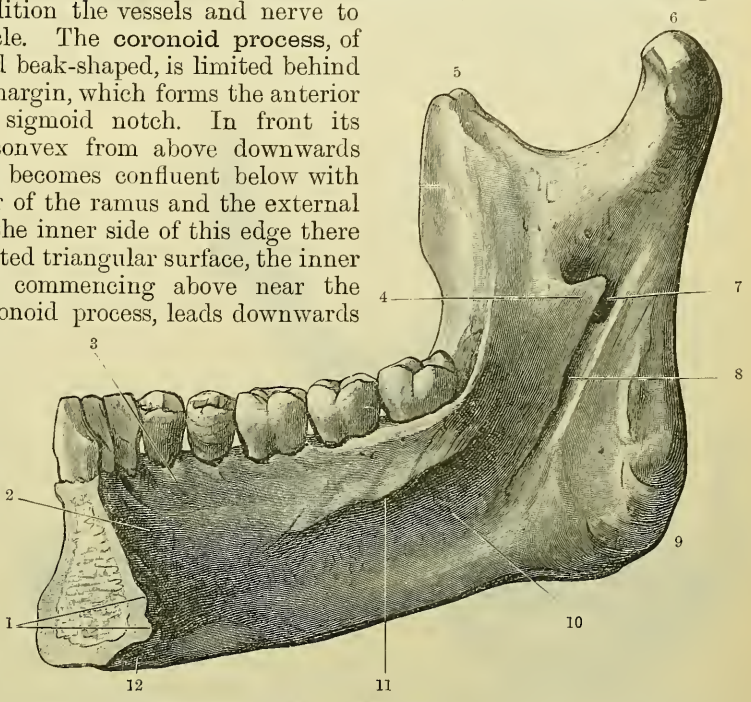


FIG. 115.—THE INNER SIDE OF THE RIGHT HALF OF THE LOWER JAW.

1. Mental spines.
2. Surface in relation to the sublingual gland.
3. Alveolar border.
4. Lingula.
5. Coronoid process.
6. Condyles.
7. Inferior dental foramen.
8. Mylo-hyoid groove.
9. Angle.
10. Fossa for submaxillary gland.
11. Internal oblique line.
12. Digastric fossa.

Architecture.—The mandible is remarkable for the density and thickness of its inner and outer walls. Where these coalesce below at the base of the body, the bone is particularly stout. Superiorly, where they form the walls of the alveoli, they gradually thin, being thicker, however, on the inner than the outer side, except in the region of the last molar tooth, where the inner wall is the thinner. The cancellous substance is open-meshed below, finer and more condensed where it surrounds the alveoli. The inferior dental canal is large and has no very definite wall; it is prolonged beyond the mental foramen to reach the incisor teeth. From it numerous channels pass upwards to the sockets of the teeth, and it communicates freely with the surrounding cancellous tissue. Above the canal the substance of the bone is broken up by the alveoli for the reception of the roots of the teeth. In the substance

of the condyle the cancellous tissue is more compact, with a general striation vertical to the articular surface.

The mental prominence is an essentially human characteristic; by some it is associated with the development of speech in man, others regard it as due to the reduction in the size of the teeth.

Variations.—Considerable differences are met with in the height of the coronoid process: usually its summit reaches the same level as the condyle, or slightly above it; occasionally, however, it rises to a much higher level; in other cases it is much reduced. These differences naturally react on the form of the sigmoid notch. The projection of the mental protuberance is also liable to vary. Occasionally the mental foramen is double, and sometimes the mylo-hyoid groove is for a short distance converted into a canal.

Ossification.—The development of the lower jaw is intimately associated with Meckel's cartilage, the cartilaginous bar of the first visceral or mandibular arch. Meckel's cartilages, of which there are two, are connected proximally with the periotic capsule and cranial base. Their distal ends are united in the region of the symphysis. It is in the connective tissue overlying the outer surface of this cartilaginous arch that the bulk of the lower jaw is developed. The cartilage itself is not converted into bone, but undergoes resorption, except its anterior extremity, which is stated to undergo ossification to form the part of the jaw lying between the mental foramen and the symphysis. In a third or fourth month fœtus the cartilage can be traced from the under surface of the fore-part of the tympanic ring downwards and forwards to reach the jaw, to which it is attached at the opening of the inferior dental canal; from this it may be traced forwards as a narrow strip applied to the inner surface of the mandible, which it sensibly grooves.

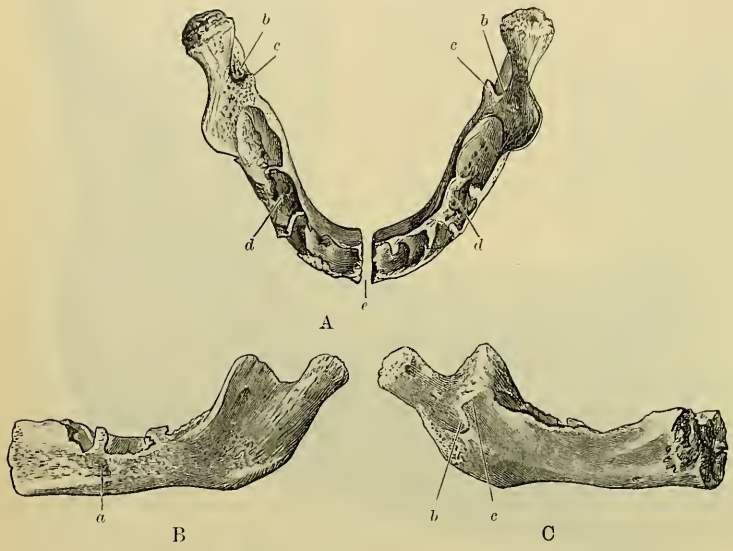


Fig. 116.—Lower Jaw at Birth. A, As seen from above; B, Outer side; C, Inner side.

a, Mental foramen; *b*, Inferior dental canal; *c*, Lingula; *d*, Sockets for the dental sacs

The proximal end of this furrow remains permanently as the mylo-hyoid groove. The part of the cartilage between the tympanic ring and the jaw becomes converted into fibrous tissue, and persists in the adult as the so-called internal lateral ligament of the temporo-maxillary articulation, its proximal end through the Glaserian fissure being continuous with the slender process of the malleus. J. Chaine (*Comptes Rendus.* Biologie, 1903) takes exception to this view and regards the internal lateral ligament as the remnant of a muscular slip. The part which is applied to the inner surface of the lower jaw disappears. In the tissue overlying the cartilage ossification begins by several centres as early as the sixth or seventh week of fœtal life, in this respect resembling the clavicle, by which it is alone preceded. The dentary or basal centre forms the outer wall and lower border. With this is united the splenial portion, which appears somewhat later, forming the inner table from near the symphysis backwards towards the opening of the inferior dental canal where it terminates in the lingula. By the union of these two parts a groove is formed, which ultimately becomes covered in, and in which the inferior dental nerve and vessels are lodged. As has been already stated, the part of the body between the symphysis and the mental foramen is regarded as directly developed by the ossification of the fore-part of the Meckelian cartilage. As will have been gathered from the above description, the upper part of the ramus and its processes have no connexion with Meckel's cartilage. The condyle and the coronoid process are each developed from a separate centre, preceded by a cartilaginous matrix. These several centres are all united about the fourth month.

At birth the lower jaw consists of two lateral halves united at the symphysis by fibrous

tissue; towards the end of the first, or during the second year, osseous union between the two halves is complete. In infancy the jaw is shallow and the rami proportionately small; further, owing to the obliquity of the ramus the angle is large, averaging about 150°. The mental foramen lies near the lower border of the bone. Coincident with the eruption of the teeth and the use of the jaw in mastication, the rami rapidly increase in size, and the angle becomes more acute. After the completion of the permanent dentition it approaches more nearly a right angle varying from 110° to 120°. The body of the bone is stout and deep, and the mental foramen usually lies midway between the upper and lower borders. As age advances, owing to the loss of the teeth and the consequent shrinkage and absorption of the alveolar border of the bone, the body becomes narrow and attenuated, and the mental foramen now lies close to the upper border. At the same time the angle opens out again (130° to 140°), in this respect resembling the infantile condition. In old age the coronoid process and the condyle form a more open angle with each other than in the adult.

The Hyoid Bone.

The **hyoid bone** (os hyoideum), or **os linguæ**, though placed in the neck, is developmentally connected with the skull. It lies between the mandible above and the larynx below, and is connected with the root of the tongue. Of U-shaped form, as its name implies (Greek *υ* and *εἶδος*, like), it consists in the adult of a central part, or **body**, with which on either side are united two long processes extending backwards—the **great cornua**. At the point where these are ossified with the body, the **lesser cornua**, which project upwards and backwards, are placed.

The **body** (basis) is arched from side to side and compressed from before backwards, so that its surfaces slope downwards and forwards. Its *anterior surface* displays a slight median ridge, on either side of which the bone is marked by the attachment of the mylo-hyoid muscles. Its *posterior surface*, deeply hollowed, is concave from side to side and from above downwards. Herein lie a quantity of fat and a bursa which separates this aspect from the thyro-hyoid membrane. The upper border is broad; it is separated from the anterior surface by a transverse ridge, behind which are the impressions for the attachment of the genio-hyoid muscles. Its hinder edge is thin and sharp; to this, above, are attached the genio-glossi, whilst behind and below the thyro-hyoid membrane is connected with it. The inferior border is well defined and narrow; it serves for the attachment of the omo-hyoid, sterno-hyoid, thyro-hyoid, and stylo-hyoid muscles.

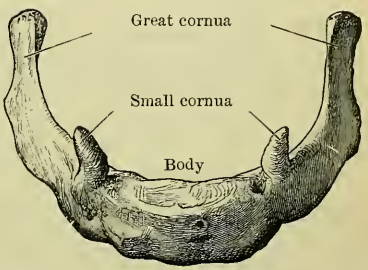


Fig. 117.—The Hyoid Bone as seen from the Front.

The **great cornua** are connected on either side with the lateral parts of the body. At first, union is effected by synchondroses, which, however, ultimately ossify. These cornua curve backwards as well as upwards, and terminate in more or less rounded and expanded extremities. Compressed laterally, they serve for the attachments externally of the thyro-hyoid and hyo-glossi muscles, and the middle constrictor of the pharynx from below upwards, whilst internally they are connected with the lateral expansions of the thyro-hyoid membrane, the free edges of which are somewhat thickened, and connect the extremities of the great cornua with the ends of the superior cornua of the thyroid cartilage below.

The **lesser cornua**, frequently cartilaginous in part, are about the size of grains of wheat. They rest upon the upper surface of the bone at the junctions of the great cornua with the body. In youth they are separated from, but in advanced life become ossified with, the rest of the bone, from which they are directed upwards, backwards, and a little outwards. Their summits are connected with the stylo-hyoid ligaments; they also serve for the attachment of muscles.

Connexions.—The hyoid is slung from the styloid processes of the temporal bones by the stylo-hyoid ligaments. Inferiorly it is connected with the thyroid cartilage of the larynx by the thyro-hyoid ligaments and membrane. Posteriorly it is intimately associated with the epiglottis.

Ossification.—In considering the development of the hyoid bone it is necessary to refer to the arrangement and disposition of the cartilaginous bars of the second and third visceral arches. That of the second visceral arch, the hyoid bar—or Reichert's cartilage, as it is sometimes called—is united above to the petrous temporal, whilst ventrally it is joined to its fellow of the opposite side by an independent mesial cartilage. Chondrification of the third visceral arch only occurs towards its ventral extremity, forming what is known as the thyro-hyoid bar. This also unites with the mesial cartilage above mentioned. In these cartilaginous processes ossific centres appear in certain definite situations. Towards the end of fœtal life a single centre (by some authorities regarded as primarily double) appears in the mesial cartilage, and forms the body of the bone (**basihyal**). About the same time ossification begins in the lower ends of the thyro-hyoid bars, and from these the great cornua are developed (thyro-hyals). During the first year the lower ends of the hyoid bars begin to ossify and form the lesser cornua (cerato-hyals). The cephalic ends of the same cartilages meanwhile ossify to form the styloid processes (stylo-hyals) (see p. 121), whilst the intervening portions of cartilage undergo resorption and become converted into the fibrous tissue of the stylo-hyoid ligaments, which in the adult connect the lesser cornua with the styloid processes of the temporal bone. The great cornua fuse with the body in middle life; the lesser cornua only at a more advanced period. Variations in the course of development lead to interesting anomalies of the hyoid apparatus. The lesser cornua may be unduly long or the stylo-hyoid ligament may be bony; in this case the cartilage has not undergone resorption, but has passed on to the further stage of ossification, thus forming an epihyal element comparable to that in the dog. The ossified stylo-hyoid ligament, as felt through the pharyngeal wall, may be mistaken for a foreign body. (Farmer, G. W. S., *Brit. Med. Journ.* 1900, vol. i. p. 1405.)

THE SKULL AS A WHOLE.

The skull as a whole may be studied as seen from the front (norma frontalis), from the side (norma lateralis), from the back (norma occipitalis), from above (norma verticalis), and from below (norma basalis).

Norma Frontalis.

In front, the smooth convexity of the frontal bone limits this region above, whilst inferiorly, when the lower jaw is disarticulated, the teeth of the upper jaw form its lower boundary. The large openings of the **orbits** are seen on either side; whilst placed mesially and at a somewhat lower level is the **anterior nasal aperture** (apertura pyriformis) leading into the **nasal fossæ**.

The **frontal region**, convex from above downwards and from side to side, is limited externally by two ridges, which are the anterior extremities of the temporal lines. Superiorly the fulness of the bone blends with the convexity of the vertex. Inferiorly the frontal bone forms on either side the arched superior border of the orbit (margo supraorbitalis). The space between these borders corresponds to the root of the nose, and here are seen the sutures which unite the frontal with the nasal bones in the middle line, and with the nasal process of the superior maxilla on either side, called the **naso-frontal** and **fronto-maxillary sutures** respectively. The orbital arch is thin and sharp externally, but becomes thick and more rounded towards its inner side, where it forms the **internal angular process** and unites with the frontal process of the superior maxilla and the lachrymal bone on the inner wall of the orbit. This arched border is interrupted towards the inner side by a notch (incisura supraorbitalis), sometimes converted into a foramen, for the transmission of the supraorbital nerve and artery. In the middle line, just above the naso-frontal suture, there is often the remains of a median suture (sutura frontalis), which marks the fusion of the two halves from which the bone is primarily ossified. Here also a prominence, of variable extent—the **glabella**—is met with; from this there passes out on either side above and over the orbital margin a projection called the **superciliary ridge** (arcus superciliaris).

The **orbital fossæ**, of more or less conical form, display a tendency to assume the shape of four-sided pyramids by the flattening of the superior, inferior, and lateral walls. The *base*, which is directed forwards and a little outwards,

corresponds to the orbital aperture. The shape of this is liable to individual and racial variations, being nearly circular in the Mongoloid type, whilst it displays a more or less quadrangular form in Australoid skulls. The upper margin, as has been already stated, is formed by the frontal bone between the internal and external angular processes. The outer, and about half the lower, margin are formed by the sharp curved edge between the facial and orbital surfaces of the malar bone. The internal border and the remainder of the lower margin are determined by the outer surface of the frontal process of the superior maxilla, and the sharp edge separating the facial from the orbital surface of the same bone. Three sutures interrupt the continuity of the orbital margin—the **fronto-malar** (sutura zygomatico-frontalis) externally, the **fronto-maxillary** (sutura fronto-maxillaris) internally, both lying about the same level, and the **malo-maxillary** (sutura zygomatico-maxillaris) inferiorly. The *apex* of the space is directed backwards and inwards, so that the inner walls of the two orbits lie nearly parallel to each other, whilst the outer walls are so disposed as to form nearly a right angle with each other. The depth of the orbit measures, on an average, about two inches (5 cm.). At the apex there are two openings; the larger, known as the **sphenoidal fissure** (fissura orbitalis superior), passes from the apex of the space outwards and a little upwards for the distance of three-quarters of an inch or so, between the roof and outer wall of the orbit. The inner third of this fissure is broad and of circular form. Externally it is considerably reduced in width. Through this the third, fourth, ophthalmic division of the fifth, and the sixth nerves enter the orbit, whilst the ophthalmic veins pass backwards through it. Above and internal to the inner end of the sphenoidal fissure there is a smaller circular opening, the **optic foramen** (foramen opticum), for the transmission of the optic nerve and ophthalmic artery.

The *roof of the orbit*, which is very thin and brittle towards its centre, is formed in front by the **orbital plate** of the **frontal bone** (pars orbitalis) and behind by a small triangular piece of the **lesser wing** of the **sphenoid**, which surrounds the optic foramen and forms the upper border of the sphenoidal fissure. Externally this surface is separated from the outer wall by the sphenoidal fissure posteriorly, anteriorly by an irregular suture between the orbital part of the frontal and the upper margin of the orbital surface of the great wing of the sphenoid, external to which the external angular process of the frontal articulates with the malar. Internally the roof is marked off from the inner wall by a suture, more or less horizontal in direction, between the orbital plate of the frontal and the following bones in order from before backwards, viz. the frontal process of the superior maxilla, the lachrymal bone, and the os planum of ethmoid. In the suture between the last-mentioned bone and the frontal there are two foramina, the **anterior** and **posterior internal orbital** or **ethmoidal canals** (foramen ethmoidale anterius et posterius); both transmit ethmoidal vessels—the anterior affording passage to the nasal nerve as well. The roof is concave from side to side, and to some extent also from before backwards. About midway between the fronto-maxillary suture and the supraorbital notch or foramen, but within the margin of the orbit, there is a small **depression**, occasionally replaced by a spine (fovea vel. spina trochlearis), for the attachment of the cartilaginous pulley of the superior oblique muscle of the eyeball. Under cover of the external angular process the roof is more deeply excavated, forming a shallow **fossa** for the lodgment of the lachrymal gland (fossa glandulæ lachrymalis). In front, the roof separates the orbit from the **frontal sinus**, and along its inner border it is in relation with the **ethmoidal air-cells**. The relation to these air spaces is variable, depending on the development and size of the sinuses. The rest of the roof, which is very thin, forms by its upper surface the floor of the anterior cranial fossa, in which are lodged the frontal lobes of the cerebrum.

The *floor of the orbit* is formed by the **orbital plate** of the **superior maxilla**, together with part of the **orbital surface** of the **malar bone**, and a small triangular piece of bone, the **orbital process** of the **palate**, which is wedged in posteriorly. Externally, for three-quarters of its length posteriorly, it is separated from the outer wall, which is here formed by the great wing of the sphenoid, by a cleft called the **spheno-maxillary fissure** (fissura orbitalis inferior). Through this there pass the

superior maxillary division of the fifth nerve on its way to the infraorbital canal, the orbital or temporo-malar branch of the same nerve, the infraorbital vessels, and some

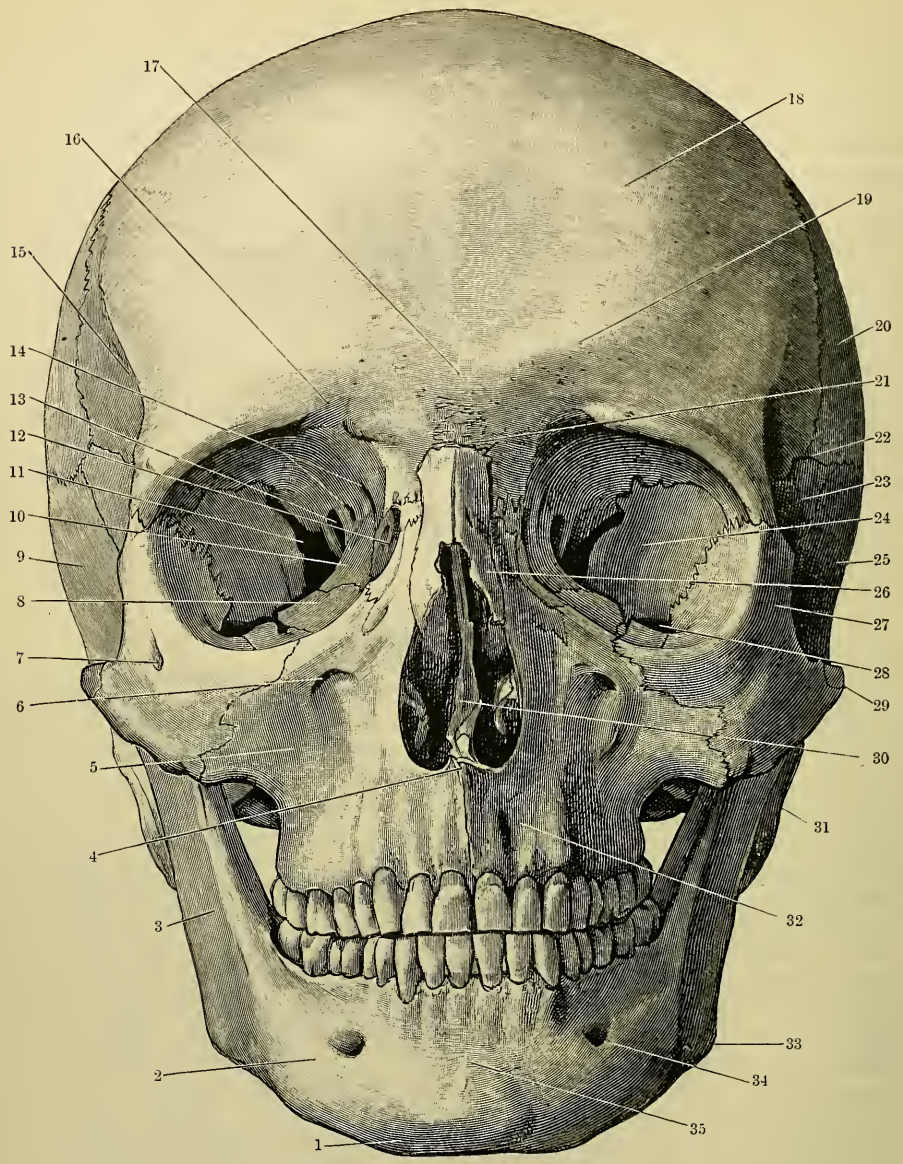


FIG. 118.—NORMA FRONTALIS.

1. Mental protuberance.
2. Body of lower jaw.
3. Ramus of lower jaw.
4. Anterior nasal spine
5. Canine fossa.
6. Infraorbital canal.
7. Malar canal.
8. Orbital surface of superior maxilla.
9. Temporal fossa.
10. Os planum of ethmoid.
11. Sphenoidal fissure.
12. Lachrymal bone and groove.
13. Optic foramen.
14. Orbital foramina.
15. Temporal ridge.
16. Supraorbital notch.
17. Glabella.
18. Frontal eminence.
19. Superciliary ridge.
20. Parietal bone.
21. Fronto-nasal suture.
22. Pterion.
23. Great wing of sphenoid.
24. Orbital surface of great wing of sphenoid.
25. Squamous temporal.
26. Left nasal bone.
27. Malar bone.
28. Spheno-maxillary fissure.
29. Zygomatic arch.
30. Anterior nasal aperture, displaying nasal septum and inferior and middle turbinated bones.
31. Mastoid process.
32. Incisor fossa.
33. Angle of jaw.
34. Mental foramen.
35. Symphysis.

twigs from Meckel's (spheno-palatine) ganglion. By means of this fissure the orbit communicates with the spheno-maxillary fossa behind and the zygomatic fossa to the outer side. Internally the floor is limited from behind forwards by the suture

between the following bones, viz. the orbital process of the palate below with the body of the sphenoid above and behind, and the os planum of the ethmoid above and in front—anterior to which the orbital plate of the superior maxilla below articulates with the os planum of the ethmoid and the lachrymal above and in front. At the anterior extremity of this line of sutures the inner edge of the orbital plate of the superior maxilla is notched and free between the point where it articulates with the lachrymal posteriorly and the part from which its frontal process rises. Here it forms the outer edge of a canal, down which the membranous nasal duct passes to the nose. The floor of the orbit is thin behind and at the sides, but thicker in front where it blends with the orbital margin. Passing in a sagittal direction through its substance is the infraorbital canal, the roof of which is usually deficient behind, where it becomes continuous with a broad, shallow groove, which leads forwards from the anterior margin of the spheno-maxillary fissure. This canal (canalis infraorbitalis) opens on the facial surface of the superior maxillary immediately below the orbital margin (foramen infraorbitale) and transmits the superior maxillary division of the fifth nerve, together with the infraorbital vessels. The floor forms a thin partition which separates the orbit from the antrum or sinus of the superior maxilla, which lies below. Internally it completes the lower ethmoidal air-cells, and separates the orbit from the middle meatus of the nasal fossæ.

The *outer wall of the orbit*, which is the strongest, is formed by the orbital surface of the **great wing** of the **sphenoid** and the upper part of the **orbital surface** of the **malar bone**. Above it, behind, is the **sphenoidal fissure**, whilst below, and extending much farther forward, is the **spheno-maxillary fissure**. The anterior margin of the outer wall is stout and formed by the **malar bone**, behind which, formed in part by the orbital process of the malar bone and the malar edge (margo-zygomaticus) of the great wing of the sphenoid, it forms a fairly thick partition between the orbit in front and the temporal fossa behind. Crossing this surface from above downwards, close to the anterior extremity of the spheno-maxillary fissure, is the suture between the malar bone and the great wing of the sphenoid (sutura spheno-zygomatica). This wall is pierced in front by one or two small canals (foramen zygomatico-orbitale), which traverse the malar bone and allow of the transmission of the temporal and malar branches of the orbital portion of the superior maxillary division of the fifth nerve.

The *inner wall of the orbit* is formed from before backwards by a small part of the **frontal process** of the **superior maxilla**, by the **lachrymal**, and by the **os planum** or orbital plate of the **ethmoid** (lamina papyracea ossis ethmoidalis), posterior to which is a small part of the lateral aspect of the **body** of the **sphenoid** in front of the optic foramen. Above, the orbital plate of the frontal bone forms a continuous suture from before backwards with the bones just enumerated; whilst below, the lachrymal and the os planum of the ethmoid articulate with the orbital plate of the superior maxilla; posteriorly the hinder extremity of the os planum and the fore-part of the body of the sphenoid articulate with the orbital process of the palate. The orbital surface of the lachrymal bone is divided into two by a vertical ridge—the **lachrymal crest** (crista lachrymalis posterior)—which forms in front the posterior half of a hollow, the **lachrymal groove** (sulcus lachrymalis), the anterior part of which is completed by the channelled posterior border of the **frontal process** of the **superior maxilla**. In the lachrymal groove or fossa (fossa sacci lachrymalis) is lodged the lachrymal sac, whilst passing from it and occupying the canal, of which the upper opening is at present seen, is the membranous nasal duct. The extremely thin wall of the lower part of the lachrymal fossa separates the orbit from the fore-part of the middle meatus of the nasal fossa. To the inner side of the upper and fore part of the lachrymal bone, and separated from the orbit merely by the thickness of that bone, is the passage leading from the nose to the frontal sinus (infundibulum ethmoidale), whilst the part of the bone behind the lachrymal crest forms the thin partition between the orbit and the anterior ethmoidal cells. Behind, where the body of the sphenoid forms part of the inner wall of the orbit, the **sphenoidal air sinus** is in relation to the apex of that space, though here the partition wall between the two cavities is much thicker.

The **skeleton of the face** on its *anterior surface* is formed by the two superior

maxillæ, the frontal processes of which have been already seen to pass up to articulate with the internal angular processes of the frontal bone, thus forming the lower halves of the inner margins of the orbit. Joined to the upper jaws externally are the **malar** or **cheek bones** (ossa zygomatica), which are supported by their union with the temporal bones posteriorly through the medium of the zygomatic arches. The suture which separates the malar from the superior maxilla (sutura zygomatico-maxillaris) commences above about the centre of the lower orbital margin and passes obliquely downward and outward, its lower end lying in vertical line with the outer orbital margin. The two superior maxillæ are separated by the nasal fossæ, which here open anteriorly. Above, the two nasal bones are wedged in between the frontal processes of the maxillæ; whilst below the nasal aperture, the maxillæ themselves are united in the middle line by the intermaxillary suture (sutura intermaxillaris).

The **nasal aperture** (apertura pyriformis), which lies below and in part between the orbits, is of variable shape and size—usually pyriform, it tends to be long and narrow in Europeans, as contrasted with the shorter and wider form met with in the negroid races. Its edges are formed below and on either side by the free curved margin of the body and the frontal process of the superior maxilla; and above, and partly at the sides, by the free border of the nasal bones. In the middle line, inferiorly, corresponding to the upper end of the intermaxillary suture there is an outstanding process—the **anterior nasal spine** (spina nasalis anterior) formed by the coalescence of spicules from both maxillæ; arising from this, and passing backwards and upwards, is a thin bony partition—the osseous septum of the nose. Often deflected to one or other side, it divides the cavity of the nose (cavum nasi) into a right and left half. Projecting into these chambers from their outer walls can be seen the inner surfaces and free borders of the **middle** (concha media) and **inferior** (concha inferior) **turbinated bones**, the spaces below and between which form the **inferior** and **middle meatuses** of the nose respectively.

Below the orbit, and to the outer side of the nasal aperture, the anterior or facial surface of the body of the superior maxilla (corpus maxillæ) is seen; this is continuous inferiorly with the outer surface of the alveolar process (process alveolaris), in which are embedded the roots of the upper teeth.

A horizontal line drawn round the jaw on the level of a point midway between the lower border of the nasal aperture and the alveolar edge corresponds to the plane of the **hard palate**. Below that the alveolar process separates the cavity of the mouth from the front of the face; whilst above, the large air space, the **maxillary sinus** (sinus maxillaris), or **antrum of Highmore**, lies within the body of the superior maxilla.

The **malar** or **cheek bone** (os zygomaticum) forms the lower half of the outer, and outer half of the lower border of the orbit. Its external aspect corresponds to the point of greatest width of the face, the modelling of which depends on the flatness or projection of this bone.

When the **lower jaw** (mandibula) is in position, and the teeth in both jaws are complete, the lower dental arch will be seen to be smaller in all its diameters than the upper, so that when the jaws are closed the upper teeth slightly overlap the lower both in front and at the sides. Exceptionally a departure from this arrangement is met with.

Norma Lateralis.

Viewing this aspect of the skull, in the first instance, without the lower jaw, it is seen to be formed in part by the bones of the cranium, and in part by the bones of the face. A line drawn from the fronto-nasal suture to the tip of the mastoid process serves to define roughly the boundary between these portions of the skull. Of ovoid shape, the cranium is formed above by the **frontal, parietal,** and **occipital bones** from before backwards; whilst below, included within these are the **sphenoid** and **temporal bones.** The sutures between these several bones are arranged as follows: Commencing at the external angular process of the frontal, the suture between that bone and the malar is first seen; tracing this backwards and a little

upwards, the lower edge of the frontal next articulates with the upper margin of the great wing of the sphenoid for a distance varying from three-quarters of an inch to one inch. Here the posterior border of the frontal turns upwards and slightly backwards, forming with the parietal the **coronal suture** (sutura coronalis). The lower border of the parietal bone, which is placed immediately behind the frontal, articulates

FIG. 119.—NORMA LATERALIS.

1. Mental foramen.
2. Body of lower jaw.
3. Superior maxilla.
4. Ramus of lower jaw.
5. Zygomatic arch.
6. Styloid process.
7. External auditory meatus.
8. Mastoid process.
9. Asterion.
10. Superior curved line of occipital bone.
11. External occipital protuberance.
12. Lambdoid suture.
13. Occipital bone.
14. Lambda.
15. Obelion placed between the two parietal foramina.
16. Parietal bone.
17. Lower temporal ridge.
18. Upper temporal ridge.
19. Squamous part of temporal bone.
20. Bregma.
21. Coronal suture.
22. Stephanion.
23. Frontal bone.
24. Pterion.
25. Temporal fossa.
26. Great wing of sphenoid.
27. Malar bone.
28. Malar canal.
29. Lachrymal bone.
30. Nasal bone.
31. Infraorbital canal.
32. Anterior nasal aperture.

anteriorly with the hinder part of the upper edge of the great wing of the sphenoid. The extent of this suture (sutura spheno-parietalis) is liable to very great individual variation—at times being broad, in other instances being pointed and narrow, whilst occasionally the parietal does not articulate with the sphenoid at all. Behind the spheno-parietal suture the parietal articulates with the squamous part of the temporal (sutura squamosa). This repeats to a certain extent the curve formed by the outline of the calvaria, and ends posteriorly about one inch behind the **external auditory meatus**. Here the suture alters its character and direction, and in place of being scaly, becomes toothed and irregular, uniting for the space of

an inch or so the posterior inferior angle of the parietal with the mastoid process of the temporal bone. This suture (sutura parieto-mastoid) is more or less horizontal in direction, and lies in line and on a level with the upper border of the zygomatic arch. At a point about two inches behind the external auditory meatus the posterior border of the parietal bone turns obliquely upwards and backwards, and forms with the tabular part of the occipital bone the strongly-denticulated **lambdoid suture** (sutura lambdoidea). Inferiorly this suture is continued obliquely downwards between the occipital bone and the hinder border of the mastoid portion of the temporal, where it forms the **occipito-mastoid suture** (sutura occipito-mastoidea), much simpler and less serrated than the two previously mentioned. These three sutures just described meet in tri-radiate fashion at a point called the **asterion.**

Anteriorly the curve of the squamous suture is continued downward between the anterior edge of the squamous part of the temporal and the posterior border of the great wing of the sphenoid; inferiorly it lies in plane with the middle of the zygomatic arch.

The sutures around the summit of the great wing of the sphenoid are arranged like the letter H placed obliquely, the cross-piece of the H corresponding to the spheno-parietal suture. When this is short, and becomes a mere point of contact, the arrangement then resembles the letter X. This region is named the **pterion.**

Curving over the lateral region of the calvaria in a longitudinal direction is the **temporal crest** (linea temporalis). This is often double. The lower line marks the limit of the attachment of the temporal muscle, whilst the upper ridge defines the attachment of the temporal fascia. Commencing in front at the external angular process of the frontal, the crest sweeps upwards and backwards across the lower part of that bone, and then crossing the coronal suture—a point called the **stephanion**—it passes on to the parietal, over which it curves in the direction of its posterior inferior angle. Here it is continued on to the temporal bone, where it sweeps forward to form the **supramastoid crest**, which serves to separate the squamous from the mastoid portion of the temporal bone externally. Carried forward, this ridge is seen to become continuous with the upper border of the zygomatic arch over the external auditory meatus. In front, the temporal ridge separates the temporal fossa from the region of the forehead; above and behind, it bounds the **temporal fossa** which lies within its concavity, and serves to separate that hollow from the surface of the calvaria which is overlain by the scalp. Above the level of the temporal lines the surfaces of the frontal and parietal bones are smooth, the latter exhibiting an elevation of varying prominence and position, but usually situated about the centre of the bone, called the **parietal eminence** (tuber parietale). A slight hollowing of the surface of the parietal behind and parallel to the coronal suture is not uncommon, and is referred to as the post-coronal depression. As seen in profile, the part of the calvaria behind and below the lambdoid suture is formed by the tabular part of the occipital bone. In line with the zygomatic arch this outline is interrupted by the **external occipital protuberance** or **inion** (protuberantia occipitalis externa). The projection of this point is variable; but its position can usually be easily determined in the living. Passing forwards from it, and blending anteriorly with the posterior border of the mastoid process of the temporal bone, is a rough crest, the **superior curved line** (linea nuchæ superior), a little above which there is often a much fainter line, the **highest curved line** (linea nuchæ suprema); this affords attachment to the epicranial aponeurosis. These two lines serve to separate the part of the cranium above, which is covered by scalp, from that below, which serves for the attachment of the fleshy muscles of the back of the neck, the latter surface (planum nuchale) being rough and irregular as contrasted with the smooth superior part (planum occipitale). The fulness of these two parts of the occipital bone varies much. There is frequently a pronounced bulging of the planum occipitale, and the position of the lambda can often be easily determined in the living; similarly the planum nuchale may be either comparatively flat or else full and rounded. These differences are of course associated with corresponding differences in the development of the cerebral and cerebellar lobes which are lodged in relation to the internal aspect of these parts of the bone.

The further description of the planum nuchale is best deferred till the base of the skull (norma basalis) is studied.

Temporal Fossa.—Within the limits of the temporal lines the side of the cranium slopes forwards, inwards, and downwards, thus leaving a considerable interval between its lower part and the **zygomatic arch.** This space or hollow is called the temporal fossa (fossa temporalis); bounded above and behind by the temporal lines, its inferior limit is defined by the level of the zygomatic arch. Deepest opposite the angle formed by the frontal and temporal processes of the malar bone, the fossa becomes shallow towards its circumference. Its floor, which is slightly concavo-convex from before backwards about mid-level, is formed above by the temporal surface (facies temporalis) of the frontal, behind by the anterior inferior angle (angulis sphenoidalis) of the parietal, as well as the lower portion of that bone, below the temporal crest; below and in front by the temporal surface of the great wing of the sphenoid, and behind and below by the squamous portion of the temporal bone. Inferiorly the floor is limited in front by the free inferior border of the great wing of the sphenoid, which forms the upper boundary of the **spheno-maxillary fissure**; behind that, by a rough ridge, the **infratemporal crest** or **pterygoid ridge** (crista infratemporalis), which crosses the external surface of the great wing of the sphenoid, to become continuous posteriorly with a ridge on the lower surface of the squamous temporal, from which the anterior root of the zygomatic process springs. In front the temporal fossa is separated from the orbit by the external angular process of the frontal above, and by the orbital process of the malar and its junction with the external border of the great wing of the sphenoid between the orbital and temporal surfaces of that process. Externally and in front, the fossa is overhung by the backward projection of the frontal process of the malar bone, and it is under cover of this, and within the angle formed by the frontal and orbital processes of the malar, that we see the opening of the **temporal canal**, which pierces the orbital plate of the malar and transmits the temporal branch of the orbital nerve—a filament of the superior maxillary division of the V nerve. The fore-part of the **spheno-maxillary fissure** (fissura orbita inferior) opens into the lower part of the temporal fossa, and thus establishes a communication between it and the orbit. If the floor of the fossa be carefully examined, some more or less distinct **vascular grooves** may be seen. One passing upwards over the posterior part of the squamous temporal, immediately in front of and above the external auditory meatus, is for the middle temporal artery; two others, usually less distinct, pass up, one over the temporal surface of the great wing of the sphenoid, the other over the fore-part of the squamous temporal; these are for the anterior and posterior deep temporal branches of the internal maxillary artery. The fossa contains the temporal muscle with its vessels and nerves, together with the temporal branch of the orbital nerve and some fat; all of which are enclosed by the fascia which stretches over the space from the upper temporal line above to the superior border of the zygomatic arch below. The extent of the fossa depends on the size of the temporal muscle, the development of which is correlated with the size and weight of the lower jaw.

Springing from the front and lower part of the squamous temporal is the **zygomatic process** of that bone; it has two roots, an anterior and a posterior, between and below which are placed the **glenoid fossa** (fossa mandibularis) in front, and the opening of the **external auditory meatus** behind. Of compressed triangular form, the process at first has its surfaces directed upwards and downwards, but curving outwards and forwards, it twists on itself, so that its narrowed surfaces are now turned outwards and inwards, and its edges upwards and downwards; passing forwards, it expands somewhat, and ends in an oblique serrated surface, which unites with the temporal process of the malar bone and completes the **zygomatic arch.** It is the upper edge of this bridge of bone which forms the posterior root. The lower border, turning inwards, forms the anterior root, and serves to separate the temporal from the zygomatic surface of the squamous temporal, blending in front with the **infra-temporal crest** on the outer surface of the great wing of the sphenoid. The under surface of this root is convex from before backwards, and is thrown into relief by the **glenoid hollow**, which passes up behind it. In this way a downward projection, which is called the **eminentia articularis**, is formed.

The **alar spine** of the **sphenoid** (spina angularis) lies immediately to the inner side of the articular part of the glenoid fossa. Its size and projection vary. It is well to remember its relation to the condyle of the lower jaw when that bone is in position; lying, as it does, to the inner side and a little in front of that process, it affords attachment to the so-called long internal lateral ligament (spheno-mandibular) of the temporo-maxillary articulation. As will be seen hereafter, the anterior extremity of the osseous Eustachian canal lies immediately to its inner side (p. 164). A noteworthy feature about the articular part of the glenoid fossa is the thinness of the bony plate which serves to separate it from the middle cranial fossa above. The **vaginal process** is a crest of bone which runs obliquely forwards from the front and inner side of the mastoid process, just below the external auditory meatus, to the alar spine of the sphenoid. Passing downwards and slightly forwards from the centre of this, and ensheathed by it in front and at the sides, is the pointed **styloid process**, the length of which is extremely variable.

In the recess between the posterior root of the zygoma and the upper curved edge of the meatus there is usually a depression, though in some instances this may be replaced by a slight bulging of the bone. If from the posterior root of the zygoma a vertical line be let fall, tangential to the posterior edge of the meatus, a small triangular area is mapped off which has been named by Macewen the **supra-meatal triangle**. Surgically this is of importance, as it is the spot selected in which to trephine the bone to reach the **mastoid antrum** (see p. 120).

In the suture between the posterior border of the mastoid-temporal and the tabular plate of the occipital, there is usually a **foramen (mastoid)** for the transmission of an emissary vein from the lateral sinus within the cranium to the cutaneous occipital vein of the scalp; this opening, which may be double, varies greatly in size, and is usually placed on a level with the external auditory meatus.

Zygomatic Fossa.—The side of the cranium in front of the anterior root of the zygomatic process of the temporal bone is deeply hollowed, forming the **zygomatic** or **infratemporal fossa** (fossa infratemporalis); this in topographical anatomy corresponds to the pterygo-maxillary region. The student must bear in mind that, in examining this space, the ramus and coronoid process of the lower jaw form its outer wall; but this bone for the present being withdrawn, enables us to get a better view of the boundaries of the space. In front its *anterior wall* is formed by the convex posterior or **zygomatic surface** (facies infratemporalis) of the **superior maxilla**, which rises behind the socket for the last molar tooth to form the **tuberosity** (tuber-maxillare). Anteriorly the zygomatic surface of the upper jaw is separated from its facial aspect by the rounded inferior margin of the malar or zygomatic process which supports the malar bone. This latter curves outwards and backwards, forming part of the upper and anterior wall of the fossa. On the inner surface of this wall will be seen the suture uniting the malar and superior maxillary bones (sutura zygomatico-maxillaris), which runs obliquely upwards and inwards to reach the external extremity of the spheno-maxillary fissure, the lower border of which forms the superior boundary of the zygomatic surface of the upper jaw. On this aspect of the bone are to be seen the openings of the **posterior dental canals** (foramina alveolaria) two or more in number, which transmit the nerves and vessels to the upper molar teeth. The *inner wall* of the zygomatic fossa is formed by the outer surface of the **external pterygoid plate** (lamina lateralis processus pterygoidei), the width and shape of which varies greatly; its posterior border is thin and sharp, and often furnished with spiny points, to one of which the ptery-go-spinous ligament, which stretches from this border to the alar spine of the sphenoid, is attached. It occasionally happens that this ligament becomes ossified. Anteriorly the external pterygoid plate is separated from the superior maxilla above by an interval called the **pterygo-maxillary fissure**. Below this the bones are apparently fused, but a careful inspection of the skull, together with an examination of the disarticulated bones, will enable the student to realise that, wedged in between the two bones at this point, is a part of one of the smaller bones of the face, the **tuberosity** of the **palate bone** (processus pyramidalis ossis palatini).

The lower border of the external pterygoid plate is usually curved and slightly

everted. Superiorly, where the external pterygoid plate is generally narrower, it sweeps upwards to become continuous with the broad under surface of the great wing of the sphenoid; this, which overhangs in part the zygomatic fossa superiorly, is limited above by the **infratemporal crest** which separates its zygomatic from its temporal surface. The zygomatic surface of the great wing of the sphenoid is limited in front and below by the edge which forms the upper boundary of the spheno-maxillary fissure, whilst behind it reaches as far back as the inner extremity of the Glaserian fissure, where it terminates in the alar spine. It is from this point that the suture (sutura spheno-squamosa) curves forward and upwards to reach the region of the pterion. The infratemporal or zygomatic surface of the great wing of the sphenoid, and the outer surface of the external pterygoid plate, alike afford extensive attachments for the external pterygoid muscle, whilst the former is pierced by minute canals for the transmission of emissary veins. Occasionally a larger vascular foramen is present (foramen Vesalii), through which a vein runs from the cavernous sinus within the cranium to the pterygoid venous plexus situated in the pterygo-maxillary region. Immediately behind the root of the external pterygoid plate there is a large oval hole, the **foramen ovale**, and behind that, and in line with the alar spine, is the smaller **foramen spinosum.** These two foramina cannot usually be seen in a side view of the skull, and are better studied when the base is examined; they are mentioned, however, because they transmit structures which here pass from and enter the cranium, viz. the inferior maxillary division of the fifth nerve, together with its motor root, and the small meningeal artery through the foramen ovale, and the middle meningeal artery and its companion veins through the foramen spinosum. A part of the squamous temporal also forms a small portion of the roof of this fossa; it consists of a triangular area immediately in front of the eminentia articularis, and between it and the anterior root of the zygomatic process of the temporal, which is here curving inwards and forwards, to become continuous with the infratemporal crest. Internally this surface is continuous with the zygomatic surface of the great wing of the sphenoid, separated from it, however, by the hinder part of the spheno-squamosal suture.

When the lower jaw is in position, the zygomatic fossa is concealed by the **ramus** of the mandible, the inner surface of which, in its upper half, forms the outer wall of that space. Viewed from the outer side, the ramus of the inferior maxilla displays considerable differences in different skulls. These are mainly due to variations in its width and in the nature of the angle which it forms at its fusion with the body of the bone. A considerable interval separates the posterior border of the ramus from the front of the mastoid process. Within this space may be seen the free inferior edge of the **tympanic plate** (vaginal process), from which, just below the external auditory meatus, the **styloid process** of the temporal bone is observed passing downwards and slightly forwards. The width and height of the **coronoid process** vary much, oftentimes reaching the level of the top of the condyle. Its extremity, when the lower jaw is closed, lies just within the fore-part of the zygomatic arch; at other times it rises to a much higher level, so that its point may be seen above the level of the upper border of the zygomatic arch. The posterior edge of the coronoid process forms the anterior border of the sigmoid notch, and limits in front the interval left between the lower border of the posterior half of the zygomatic arch and the upper hollowed edge of the ramus. On looking into this interval, the floor of the zygomatic fossa may be seen, formed anteriorly by the external pterygoid plate; whilst posteriorly it is possible to pass a probe right across the base of the skull from one sigmoid notch to the other, the shaft of the probe lying immediately behind the pterygoid processes of the sphenoid, and crossing the foramina ovalia, through which the inferior maxillary divisions of the fifth nerves pass.

The **ramus** and **coronoid process** are so placed as to occupy a position intermediate between the zygomatic arch externally and the external pterygoid plate internally; their inner surface, therefore, forms the outer wall of the zygomatic fossa. On a level with the surface of the crowns of the teeth of the lower jaw, and situated about the middle of this aspect of the ramus, is the **inferior dental foramen**

(foramen mandibulare), the superior opening of the **inferior dental canal** (canalis mandibulæ), which traverses the body of the bone. Through this foramen there pass the inferior dental branch of the inferior maxillary division of the fifth nerve, together with the inferior dental artery and its companion veins. As will now be seen, when the lower jaw is in position, the zygomatic fossa is closed in externally by the ramus of the mandible. In front there is an interval between the anterior border of the ramus and the zygomatic surface of the superior maxilla, through which pass the buccal branch of the fifth nerve and the communicating vein between the pterygoid plexus and the facial vein. Above, in the interval between the sigmoid edge and the lower border of the zygomatic arch, there pass from the fossa the vessels and nerves which supply the masseter muscle. Between the posterior border of the ramus and the styloid process there enter and leave the large vessels which are found within the space. Superiorly, under cover of the zygomatic arch, the zygomatic fossa communicates with the temporal fossa, whilst inferiorly it is continuous with the inframaxillary region. . Internally, on the floor of the fossa there is an Γ-shaped fissure, the horizontal limb of which corresponds to the **spheno-maxillary fissure**, forming a channel of communication between the fossa and the orbit, through which passes the orbital branch of the superior maxillary division of the fifth nerve; whilst the vertical cleft is the **pterygo-maxillary fissure**, which leads into a small fossa placed between the front of the root of the pterygoid process of the sphenoid and the back of the superior maxilla, called the **spheno-maxillary fossa** (fossa pterygo-palatina).

The following foramina open into the zygomatic fossa—the foramen ovale,

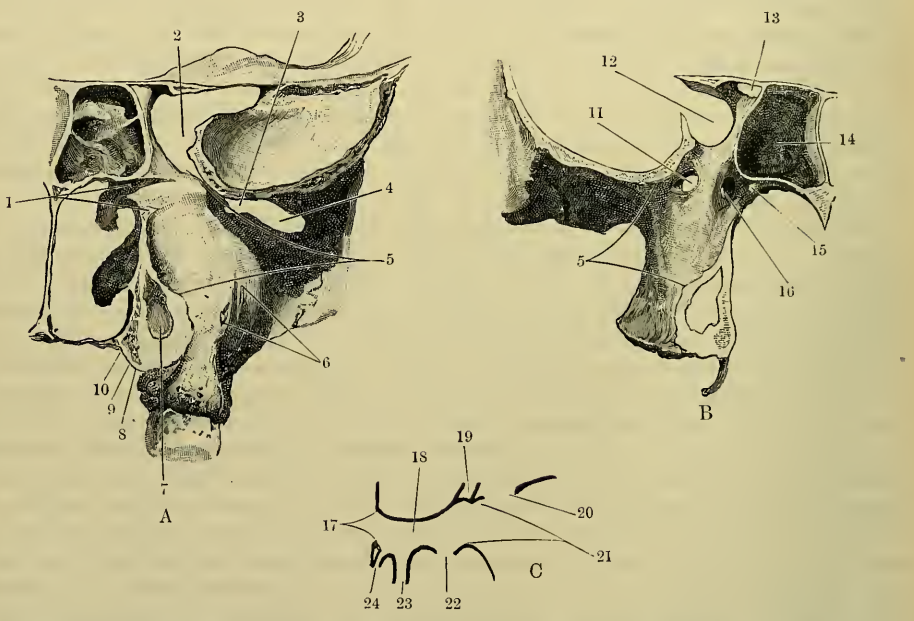


FIG. 120.—CORONAL SECTION THROUGH THE SPHENO-MAXILLARY FOSSA OF THE RIGHT SIDE.

A. Anterior Wall. B. Posterior Wall. C. Diagrammatic representation of a horizontal section across the fossa.

1. Spheno-palatine foramen.
2. Apex of orbital cavity.
3. Spheno-maxillary fissure.
4. Spheno-maxillary fissure.
5. Pterygo-maxillary fissure.
6. Dental foramina.
7. Part of pterygoid fossa.
8, 9, 10. Posterior palatine and accessory palatine canals.
11. Foramen rotundum.
12. Sphenoidal fissure.
13. Optic foramen.
14. Sphenoidal sinus.
15. Pterygo-palatine canal.
16. Vidian canal.
17. Spheno-palatine foramen.
18. Spheno-maxillary fossa.
19. Infra-orbital groove.
20. Spheno-maxillary fissure.
21. Pterygo-maxillary fissure.
22. Foramen rotundum.
23. Vidian canal.
24. Pterygo-palatine canal.

foramen spinosum, posterior dental foramina, inferior dental foramen, minute foramina for the transmission of emissary veins; of these one of large size is occasionally present, the foramen of Vesalius.

Spheno-Maxillary Fossa.—This space, which corresponds to the angular interval

between the pterygo-maxillary and spheno-maxillary fissures, and which lies between the maxilla in front and the root of the pterygoid process behind, is bounded internally by the vertical plate of the palate bone, which separates it from the nasal cavity, with which, however, it communicates by means of the spheno-palatine foramen, which lies between the orbital and sphenoidal processes of the palate bone and the under surface of the body of the sphenoid. Opening into this fossa, above and behind, are the foramen rotundum, the Vidian canal and the pterygo-palatine canal from without inwards, whilst below is the superior orifice of the posterior palatine canal, together with openings of the accessory posterior palatine canals. Its roof is formed by the under surface of the body of the sphenoid and the orbital plate of the palate bone. Anteriorly it lies in relation to the apex of the orbit, with which it communicates by means of the spheno-maxillary fissure; whilst externally, as already stated, it communicates with the zygomatic fossa through the pterygo-maxillary fissure.

Norma Occipitalis.

This view of the cranium includes the posterior halves of the two parietal bones above, the tabular part of the occipital bone below, and the mastoid portions of the temporal bones on either side inferiorly. The shape of this aspect of the skull varies much, but ordinarily the greatest width corresponds to the level of the parietal eminences. The sutures on this view of the calvaria display a tri-radiate arrangement, one limb of which is vertical, and corresponds to the posterior part of the interparietal or **sagittal suture** (sutura sagittalis). The other two limbs pass outwards and downwards in the direction of the mastoid processes, uniting the two parietal bones in front with the occipital bone behind; these constitute the Λ-shaped **lambdoid suture** (sutura lambdoidea). The point of confluence of the sagittal and lambdoid sutures is called the **lambda**. This can generally be felt in the living, owing to the tendency of the tabular part of the occipital to project slightly immediately below this spot. About one inch and a quarter above the lambda the two small **parietal foramina** (foramina parietalia) are seen, through which pass the small emissary veins of Santorini, which connect the intracranial venous system with the superficial veins of scalp. These small holes lie about $\frac{5}{16}$ of an inch apart on either side of the sagittal suture, which here, for the space of about an inch, displays a simplicity of outline in striking contrast with its serrated arrangement elsewhere. The term **obelion** is applied to a point on the sagittal suture in line with the two parietal foramina. The **lambdoid suture** is characterised by great irregularity of outline, and not unfrequently chains of separated ossicles are met with in it, the so-called **Wormian bones**. The tabular part of the occipital bone is divided into two parts by the **superior curved line** (linea nuchæ superior), the central part of which forms the **external occipital protuberance** (protuberantia occipitalis exterior). The part above, called the occipital surface (planum occipitale), comes within our present consideration; the part below, the nuchal surface (planum nuchale), though seen in perspective, had best be considered when the base is examined. A little above the level of the superior curved line the occipital surface is crossed on either side by a faint lunated line, the **highest curved line** (linea nuchæ suprema) to which are attached the occipitales muscles and the epicranial aponeurosis. The projection of the occipital surface varies much in individual skulls; most frequently it overhangs the external occipital protuberance, forming a distinct boss; exceptionally, however, the latter may be the most projecting part of the bone. The extremity of the superior curved line on either side corresponds to the position of the **asterion** (p. 154). External to these points the outline of the skull is determined by the downward projection of the mastoid processes, the inner surfaces of which are deeply grooved for the attachment of the posterior bellies of the digastric muscles, thus causing these processes to appear more pointed when viewed from this aspect.

Norma Verticalis.

This is the view of the calvaria as seen from above. It is liable to great

diversities of form. Thus its shape may vary from an elongated oval to an outline more nearly circular. These differences have been classified, and form important distinctions from a craniometrical standpoint (p. 178), the rounder varieties being termed the **brachycephalic**, whilst the elongated belong to the **dolichocephalic** group. Another noteworthy point in this view is the fact that in some instances the zygomatic arches are seen, whilst in others they are concealed by the overhang and bulge of the sides of the fore-part of the cranium. The former condition is described as **phœnozygous**, the latter as **cryptozygous**, and each is more or less closely associated with the long or round varieties of head-form respectively.

The sutures displayed have a T-shaped arrangement. Placed mesially between the two parietal bones is the **sagittal suture**. This is finely denticulated, except in the region of the obelion, though, of course, this will not be apparent if obliteration of the suture has taken place through fusion of the two parietal bones. Posteriorly the sagittal suture unites with the lambdoid suture at the **lambda**, which marks in the adult the position of the posterior fontanelle of the fœtus. Anteriorly it terminates by joining the transverse suture which separates the frontal bone anteriorly from the parietals behind; this latter is called the **coronal suture**, and the point of junction between the sagittal and coronal sutures is known as the **bregma** which corresponds in position to the anterior fontanelle of the fœtus. The summit of the vault of the calvaria corresponds to a variable point in the line of the sagittal suture, and is named the **vertex**. The **coronal suture** is less denticulated centrally than laterally. Occasionally there is a persistence of the suture which unites the two halves of the frontal bone; under these conditions the line of the sagittal suture is carried forward to the fronto-nasal suture, and a skull displaying this peculiarity is described as **metopic**. Behind the coronal suture may occasionally be seen the **post-coronal depression** (p. 154), and in some instances the vault of the calvaria forms a broad, slightly elevated crest along the line of the sagittal suture. On either side, the temporal ridges can be seen curving over the lateral and superior aspects of the parietal bones. As the lower of these crosses the coronal suture in front it marks a spot known as the **stephanion**, useful as affording a fixed point from which to estimate the bi-stephanic diameter. The interval between the temporal ridges on either side will vary according to the form of the skull and the development of the temporal muscle. In this view of the calvaria a small part of the lambdoid suture on either side of the lambda is visible posteriorly.

Norma Basalis.

The base of the cranium—*i.e.* the skull without the mandible—includes a description of the under surfaces of the **skeleton of the face** (cranium viscerale) and the **cranium** (cranium cerebrale). The former includes the **hard palate** formed by the superior maxillæ and palate bones, the **superior dental arch**, and the **bodies of the superior maxillæ** as seen from below; whilst externally, and united with the bodies of the superior maxilla, the **malar** bones are displayed, curving backwards to form the anterior halves of the **zygomatic arches**. In the middle line, passing from the upper surface of the hard palate, is the osseous septum of the nose, here formed by the vomer, which is united above to the under surface of the body of the sphenoid.

The under surface of the cranium is pierced by the **foramen magnum** for the transmission of the spinal cord and its membranes. In front of this a stout bar of bone extends forwards in the middle line, formed by the union of the body of the sphenoid in front with the basilar process of the occipital bone behind. In adult skulls all trace of the fusion of these two bones has disappeared; when union is incomplete, it indicates that the skull is that of a person below the age of twenty-five. The sphenoid comprises that part of the calvaria which forms the roof and sides of the apertures which lie on either side of the nasal septum above the hard palate —the **choanæ** or **posterior nares**. Laterally the under surfaces of the great sphenoidal wings extend as far forward as the posterior border of the **spheno-maxillary fissure**; whilst posteriorly they reach as far as the **alar spine**, external to which the spheno-squamosal suture, separating the great wing of the sphenoid from

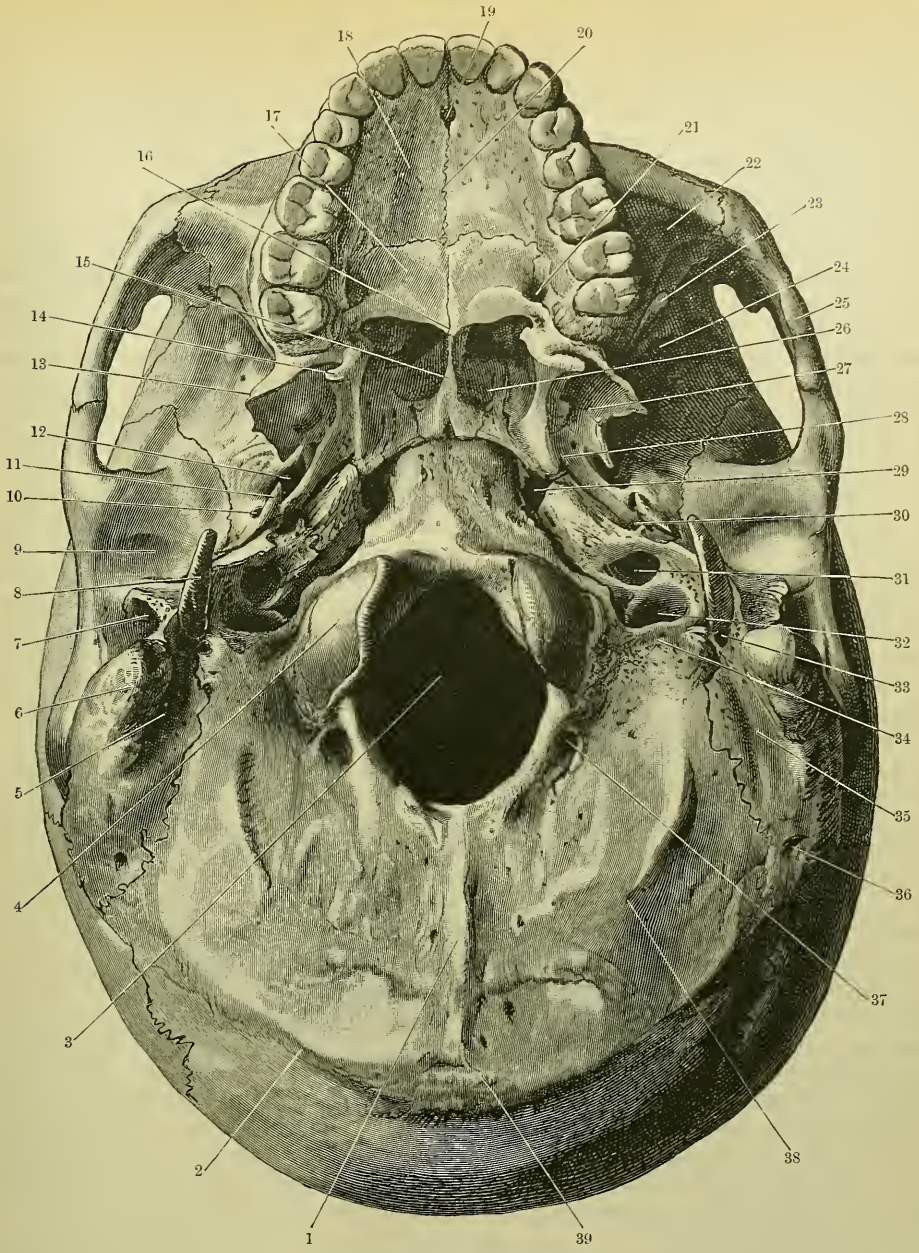


FIG. 121.—NORMA BASALIS.

1. External occipital crest.
2. Superior curved line of the occipital bone.
3. Foramen magnum.
4. Occipital condyle.
5. Digastric groove.
6. Mastoid process.
7. External auditory meatus.
8. Styloid process.
9. Glenoid fossa.
10. Foramen spinosum.
11. Sphenoidal spine.
12. Foramen ovale.
13. External pterygoid plate.
14. Hamular process of internal pterygoid plate.
15. Nasal septum.
16. Posterior nasal spine.
17. Horizontal plate of palate bone.
18. Palatal process of superior maxilla.
19. Anterior palatine canal.
20. Intermaxillary suture.
21. Posterior palatine canal.
22. Malar process of superior maxilla.
23. Spheno-maxillary fissure.
24. Zygomatic fossa.
25. Zygomatic arch.
26. Posterior opening of left nasal fossa.
27. Pterygoid fossa.
28. Scaphoid fossa.
29. Foramen lacerum medium.
30. Opening of osseous Eustachian canal.
31. Carotid canal.
32. Jugular fossa.
33. Stylo-mastoid foramen.
34. Jugular process of occipital bone.
35. Groove for occipital artery.
36. Mastoid foramen.
37. Posterior condylic foramen.
38. Inferior curved line of occipital bone
39. External occipital protuberance.

the squamous portion of the temporal, curves forwards and upwards, internal to the eminentia articularis, to reach the floor of the temporal fossa, along which its course

has been already traced (p. 155). On a level with the front of the foramen magnum the **jugular process** of the occipital bone forms an irregular curved border, which sweeps outwards to terminate at a point just internal to the root of the styloid process. Here, in line with the spheno-squamosal suture, from which, however, it is separated by a considerable interval, its extremity turns backwards, and may be traced at first internal to, and then turning upwards, behind the mastoid process of the temporal bone, separated from this latter by the occipito-mastoid suture. The bone behind the foramen magnum, which is included between the two occipito-mastoid sutures, comprises the **nuchal surface** of the tabular portion of the occipital bone, an area which is limited behind by the **superior curved line** which separates it from the occipital surface of the same bone. The remaining portions of the base of the calvaria, as at present exposed, are formed by the **squamous** and **tympanic portions** of the **temporal bone** together with the **petro-mastoid part** of the same bone, the latter of which is wedged in between the great wing of the sphenoid in front and the occipital bone behind. Stretching forwards from the squamous temporal in front is seen the **zygomatic process** which, by its union with the malar, completes the formation of the zygomatic arch.

Studying next the various parts in detail, the **hard palate** (palatum durum) may be first examined. Of horse-shoe shape as a rule, it presents many varieties of outline and size. Formed by the palatal processes (processus palatini) of the superior maxillæ in front and the horizontal plates (partes horizontales) of the palate bones behind, its circumference in front and at the sides corresponds to the **superior alveolar arch**, in which are embedded the sixteen teeth of the upper jaw; posteriorly the edge of the hard palate is thin, ending mesially in a pointed process, the **posterior nasal spine** (spina nasalis posterior), on either side of which the posterior free border is sharp and lunated. The vault of the palate, which is concave from side to side, and from before backwards, varies in depth according to the projection and development of the alveolar processes. When the teeth are shed and the alveoli are absorbed, the palate becomes shallow and flat. Running throughout its entire length in the middle line is the **middle palatine suture** (sutura palatina mediana), which separates the palatal processes of the superior maxillæ in front and the horizontal plates of the palate bones behind. A little behind the central incisor teeth, and in the line of this suture, is a little pit, the **anterior palatine canal** or **fossa** (foramen incisivum). At the bottom of this may be seen the openings of some small canals, varying in number from one to four; these are usually described as arranged in two pairs, the one pair placed side by side, the other lying mesially in front and behind. The former are called the incisor foramina, or foramina of Stenson, and transmit the terminal twigs of the superior or descending palatine arteries which ascend to reach the nasal fossæ. The latter, called the foramina of Scarpa, open, the anterior into the left, the posterior into the right nasal fossa, and afford passage for the fine filaments of the left and right naso-palatine nerves respectively. About half an inch (12 mm.) in front of the posterior nasal spine the middle palatine suture is crossed at right angles by the **transverse palatine suture** (sutura palatina transversa). This, which indicates the line of union of the palatal processes of the superior maxillæ with the horizontal plates of the palate bones, passes transversely outwards on either side until it reaches the inner aspect of the base of the alveolar process, along which it turns backward, to disappear within the **posterior palatine canal** (foramen palatinum majus), the aperture of which lies immediately internal to the root of the wisdom molar. Through this there pass the superior or descending palatine artery and the large descending palatine nerve. Leading from this foramen is a groove which curves forward immediately to the inner side of the alveolar arch; not unfrequently the inner edge of this groove forms a thin and sharp ridge on the surface of the palate. In this groove are lodged the aforementioned vessels and nerves. The surface of the palate in front of the transverse suture is rough, pitted for the palatine glands, and pierced by numerous small vascular foramina; the part of the palate behind the suture, formed by the under surface of the horizontal plate of the palate bone, is much smoother. From this there rises, just posterior to the orifice of the posterior palatine canal, a thin sharp crest which curves inwards immediately in front of the posterior free

edge; to this are attached some of the tendinous fibres of the tensor palati muscle.

Pterygoid Processes.—Buttressed against the hinder extremities of the alveolar arch are the pterygoid processes of the sphenoid. If carefully examined, these will be seen not to lie in actual contact with the maxillæ, but to be separated from them by the triangular wedge-shaped **tuberosities** (proc. pyramidales) of the palate bones. It is these latter which are pierced by the posterior and external **accessory palatine canals** (foramina palatina minora) which lie just behind the posterior palatine canal, and through which pass the lesser palatine nerves. As here displayed, the **pterygoid processes** (processus pterygoidei) of the sphenoid lie on either side of the opening of the posterior nares; each consists of two plates, an internal (lamina medialis) and an external (lamina lateralis); the latter is the broader, and is directed backwards and slightly outwards. Its external surface has been already studied in connexion with the zygomatic fossa (p. 156). Internally it is separated from the inner pterygoid plate by the **pterygoid fossa** (fossa pterygoidea), wherein is lodged a considerable part of the internal pterygoid muscle. The floor of the fossa is formed in greater part by the coalescence of the two pterygoid plates; but at the level of the hard palate the tuberosity of the palate bone appears wedged in between the two plates, and so enters into the formation of the floor of the pterygoid fossa. The internal pterygoid plate separates the nasal from the pterygoid fossa; to the hinder edge of the internal pterygoid plate are attached the pharyngeal aponeurosis, the superior constrictor of the pharynx, and the palato-pharyngeus muscle. Above, the posterior border of this plate is channelled to form the small **scaphoid fossa** (fossa scaphoidea), which curves outwards over the summit of the pterygoid fossa, and furnishes a surface for the origin of the tensor palati muscle. The sharp inner margin of this fossa, continuous below with the posterior border of the internal pterygoid plate, extends upwards, and on either side of the body of the sphenoid forms a blunt pointed process, the **pterygoid tubercle**, which extends backwards towards the apex of the petrous part of the temporal bone. Just external to this, and concealed by it, is the hinder extremity of the **Vidian canal** (canalis Vidianis), through which pass the Vidian vessels and nerve. The inner surface of the internal pterygoid plate is directed towards the nasal fossæ. Superiorly this surface curves inwards to meet the under surface of the body of the sphenoid, forming on either side a lipped edge, the **vaginal process** (processus vaginalis), between which the alæ of the vomer, which here forms the nasal septum, are wedged. Between the two a small interval, however, is occasionally left, which forms on either side the **basi-pharyngeal canal**. A little external to the line of union of the vaginal process with the vomer is the opening of the **pterygo-palatine canal** (canalis pharyngeus). This lies between the under surface of the vaginal process and the sphenoidal process of the palate bone, which here articulates with the inferior surface of the body of the sphenoid. The pharyngeal branch of the spheno-palatine ganglion and the pterygo-palatine artery pass through this canal. Inferiorly the pterygoid processes project below the level of the hard palate. The inner plate ends in a slender recurved process, called the **hamular process** (hamulus pterygoideus), which turns backwards and outwards; this is frequently broken off in skulls which have been roughly handled. It reaches as low as the level of the alveolar margin, and lies just within and behind the posterior extremity of the alveolar process. It can readily be felt in the living by placing the finger against the soft palate behind and just within the gum around the root of the wisdom tooth. On the front of and below this process the tendon of the tensor palati muscle glides in a groove.

The **posterior nares** (choanæ) lie within and between the pterygoid processes. Of a shape much resembling two Gothic windows, their bases or inferior boundaries are formed by the horizontal plates of the palate bone. Externally they are bounded by the inner surfaces of the internal pterygoid plates, whilst above, the outer side of the arch is formed by the vaginal processes of the same plate; internally they are separated by the thin vertical posterior border of the vomer, whilst above the everted alæ of the same bone form the inner sides of the arch. The plane of these apertures is not vertical but oblique, corresponding usually to a

line drawn from the bregma above through the last molar tooth of the upper jaw below. Their size varies considerably, but the height is usually equal to twice the width.

The region of the cranium which lies external to the superior maxilla and external pterygoid plate corresponds to the **zygomatic fossa**, which has been already described as seen from the side (norma lateralis, p. 156). Viewed from below, the zygomatic fossa is bounded in front by the posterior surface of the body of the superior maxilla and the internal surface of the malar bone. The roof, which is traversed by the spheno-squamosal suture, is formed in front by the under surface of the great wing of the sphenoid, and behind by a small triangular surface of the under side of the squamous part of the temporal bone immediately in front of the eminentia articularis.

Circumscribed externally and behind by the anterior root of the zygoma, which curves forward to become continuous in front with the infra-temporal crest crossing the external surface of the great wing of the sphenoid, the roof of the fossa is separated from its anterior wall by the **spheno-maxillary fissure**, which is so inclined that with its fellow of the opposite side it forms an angle of 90°. Superiorly the zygomatic fossa communicates freely with the temporal fossa beneath the zygomatic arch, though the student must bear in mind the fact that when the inferior maxilla is in position the external limits of the space are very much reduced (p. 160).

The under surface of the great wing of the sphenoid is here V-shaped. The angle corresponds to the spine, the outer limb to the spheno-squamosal suture, whilst the inner limb corresponds to a narrow cleft, the fissura spheno-petrosa, which separates it from the petrous portion of the temporal bone to which it is united in the recent condition by a synchondrosis. Along the line of this latter fissure the edges of the adjacent bones (sphenoid and petrous temporal) are bevelled so as to form a groove, which extends from the root of the inner pterygoid plate internally, to the inner side of the base of the alar spine externally, where the groove ends by entering an osseous canal. In the groove (sulcus tubæ auditivæ) is lodged the cartilaginous part of the **Eustachian tube**, whilst the osseous canal includes the bony part of the same tube, together with the tensor tympani muscle, which is lodged in a separate compartment immediately above it. The anterior extremity of the cartilaginous part of the Eustachian tube is supported by the posterior edge of the internal pterygoid plate, which is often notched for its reception. Between the root of the external pterygoid plate and the alar spine there are two foramina which lie immediately in front of the sulcus tubæ auditivæ. Of these the larger and anterior is the **foramen ovale**, through which pass the motor root and inferior maxillary division of the fifth nerve, together with the small meningeal artery. The smaller, which from its position immediately in front of the alar spine is called the **foramen spinosum**, transmits the middle meningeal artery and sympathetic plexus surrounding that vessel. The lesser superficial petrosal nerve here passes through the base of the skull to join the otic ganglion either through a small foramen (canalis innominatus) placed between the foramen ovale and the foramen spinosum, or through the foramen ovale or through the spheno-petrosal fissure. The position of the suture between the basi-occipital and basi-sphenoid corresponds to a line connecting the tips of the pterygoid tubercles at the root of the internal pterygoid plates.

Occasionally in the centre of this line there is a small pit with a foramen leading from it. This probably represents the lower end of the cranio-pharyngeal canal.

The under surface of the **basi-occipital** (pars basilaris) stretches between the body of the sphenoid in front and the anterior margin of the foramen magnum behind; projecting from its centre is a slight elevation, the **pharyngeal tubercle** (tuberculum pharyngeum), to which the pharyngeal aponeurosis, together with the central part of the anterior occipito-atlantal ligament, is attached. It should be noted, that when the atlas is in position the pharyngeal tubercle lies in line with the tubercle on the anterior arch of that bone. Curving outwards and backwards from the pharyngeal tubercle, on either side, is an irregular ridge (crista muscularis), in front and behind which are attached the rectus capitis anticus major and minor

muscles. On either side of the basi-occipital, in front, there is an irregular opening of variable size; this is placed between the root of the pterygoid process anteriorly, the apex of the petrous portion of the temporal bone externally, and the outer edge of the basi-occipital and basi-sphenoid internally. It is called the **foramen lacerum medium.** Opening into it in front, just external to the pterygoid tubercle, is the **Vidian canal,** whilst in correspondence with the apex of the petrous temporal the large orifice of the **carotid canal** may be seen entering it behind and from the outer side. In the recent condition the lower part of the foramen lacerum is occupied by fibro-cartilage, over the upper surface of which the internal carotid artery and great superficial petrosal nerve pass to reach their respective foramina, whilst a small meningeal branch of the ascending pharyngeal occasionally enters the cranium through it. Leading outwards from the foramen lacerum in the direction of the alar spine of the sphenoid is the spheno-petrosal fissure, which lies at the bottom of the **sulcus tubæ auditivæ,** and disappears from view within the **bony Eustachian canal.** Passing backwards from the foramen lacerum there is a fissure between the outer side of the basi-occipital and the posterior and inner border of the petrous part of the temporal bone. This, which is called the **petro-occipital fissure** (fissura petro-occipitalis), opens posteriorly into the **jugular foramen.** In the recent condition the fissure is filled up with cartilage. The under surface of the petrous bone included between these two fissures is rough and irregular, and affords attachments near its apex to two small muscles, the levator palati and the tensor tympani. Immediately behind the alar spine the petrous temporal is pierced by a circular hole, the inferior opening of the **carotid canal** (canalis caroticus). This passes upwards, and then turns inwards and forwards towards the apex of the bone, where it may again be seen opening into the outer and upper side of the foramen lacerum. Externally the wall of the vertical part of this canal which is usually very thin, separates it from the cavity of the tympanum, as may be seen by holding the skull up to the light and looking into the external auditory meatus (p. 118). The carotid canal transmits the internal carotid artery, together with the sympathetic plexus around it. It is noteworthy that the two carotid canals lie in line with the anterior edges of the two external auditory meatuses.

The **jugular foramen** is an opening of irregular shape and size placed between the petrous temporal in front and the jugular process of the occipital bone behind. The former is excavated into a hollow called the **jugular fossa,** which forms a roof to the upper and outer part of the space, whilst the latter, by a curved edge, either rounded or sharp, constitutes its posterior border. There is often considerable difference in the size of the jugular foramina; that on the right side (with the skull in its normal position) is usually the larger. The foramen is occasionally subdivided into two by spicules of bone which bridge across it. Lodged within the fossa is the sinus of the internal jugular vein, in front of which the inferior petrosal sinus passes down to join the internal jugular vein below the foramen. Effecting an exit between the two veins, in order from before backwards, are the glosso-pharyngeal, pneumogastric, and spinal accessory nerves. Small meningeal branches from the ascending pharyngeal and occipital arteries also enter the foramen. The two jugular foramina lie in line with a line drawn through the centres of the two external auditory meatuses. Following the direction of a line connecting the alar spine of the sphenoid and the mastoid process of the temporal, and placed immediately external to the apertures of the carotid canal and jugular foramen, is the **vaginal process** of the tympanic plate of the temporal bone, the edge of which is sharp and thin, and serves to separate the under surface of the petrous temporal from the non-articular part of the glenoid fossa. Springing from this crest immediately external to the jugular fossa, and in line with the middle of the external auditory meatus, is the **styloid process** (processus styloideum) of the temporal bone (p. 116). Its relation to the jugular foramen is of great importance, as the internal jugular vein lies immediately to its inner side.

Immediately behind the root of the styloid process, internal to and in line with the front of the mastoid process, is the **stylo-mastoid foramen** (foramen stylo-mastoideum), the lower aperture of the aquæductus Fallopii through which the facial nerve passes out and the stylo-mastoid branch of the posterior auricular artery

passes in. The inner surface of the mastoid process is deeply grooved at its base for the origin of the posterior belly of the digastric muscle. Internal to this, and running along, just wide of the occipito-mastoid suture, is a shallow groove in which the occipital artery is lodged. Immediately internal to the stylo-mastoid foramen is the synchondrosis between the extremity of the **jugular process** (processus jugularis) of the occipital bone and the petrous temporal. The former is a bar of bone which limits the jugular fossa posteriorly and abuts on the occipital condyles internally; its under surface is convex from before backwards and affords attachment to the rectus lateralis muscle. The **occipital condyles** (condyli occipitales) are placed between the jugular processes and the foramen magnum. Limited in front by a rounded thickening which becomes confluent with the anterior border of the foramen magnum, they form by their inner sides the lateral boundaries of that aperture on its anterior half. Externally they are continuous with the jugular processes, in front of which they overhang a fossa which is pierced behind by the **anterior condylic foramen** (canalis hypoglossi), through which passes the hypoglossal nerve, together with a small vein and occasionally a small meningeal branch derived from the ascending pharyngeal artery.

The **posterior condylic fossæ** are situated just behind the posterior extremities of the condyles. Not unfrequently their floor is pierced by the **posterior condylic foramen** (canalis condyloideus), through which the posterior condylic vein emerges. The base of the skull behind the jugular processes and condyles of the occipital bone is formed by the nuchal surface (planum nuchale) of the tabular plate of that bone. Posteriorly this surface is bounded by the **superior curved line**, in the centre of which is placed the projecting external occipital protuberance. Laterally the tabular plate is separated from the mastoid portion of the temporal bone by the occipito-mastoid suture, which curves backwards and outwards, from the extremity of the jugular process in front, around the base of the mastoid process behind. In front and in the middle line this plate of bone is pierced by the **foramen magnum**, the anterior half of which has been already seen to lie between the occipital condyles. Usually of oval form, though in some cases it tends to approach the circular, the plane of this opening is inclined downwards and slightly forwards. The extreme anterior edge of the foramen is sometimes called the **basion**, whilst the extreme posterior margin is termed the **opisthion**. The lower border of the medulla oblongata, where it becomes continuous with the spinal cord, is lodged within the foramen, together with the meninges which cover it, whilst the vertebral arteries and the spinal portions of the spinal accessory nerves pass upwards through it. The anterior and posterior spinal arteries, some small veins, and the roots of the first cervical nerves, also traverse it from above downwards.

The student will, no doubt, experience considerable difficulty in bearing in mind the relative positions of the various foramina and processes which he has studied on the under surface of the base of the skull.

If a line be drawn on either side from the anterior palatine canal in front, through the stylo-mastoid foramina posteriorly, it will be found to cut or pass near to the following objects:—On the hard palate it will lie close to the posterior and accessory palatine canals. It will then pass between the hamular process and the external pterygoid plate overlying the foramen ovale, the foramen spinosum, the opening of the osseous Eustachian canal and the spine of the sphenoid; behind this it will cut through the root of the styloid process and define externally the limits of the jugular fossa. After passing through the stylo-mastoid foramen, if the line be prolonged backwards it will usually be found to pass over the mastoid foramen in the occipito-mastoid suture. Another line of much value is one drawn across the base of the skull from the centre of one external auditory meatus to the other. This will be found to pass through the root of the styloid process, the jugular foramen, the anterior condylic foramen; it then crosses the front of the occipital condyles, and corresponds with the anterior edge of the foramen magnum.

A line which may be found useful is one drawn from the stylo-mastoid foramen of one side to the posterior palatine canal of the opposite side. This will be seen to overlie, from behind forwards, the outer part of the jugular foramen and the inferior opening of the carotid canal. The line indicates the direction of the carotid canal, and cuts the foramen lacerum medium anteriorly; in front of this it usually corresponds to the position of the posterior aperture of the pterygo-palatine canal.

The examination of the base of the skull is incomplete unless the student examines it with the lower jaw and atlas vertebra in position. The relation of the ramus of the lower jaw to the zygomatic fossa has been already sufficiently studied (p. 157);

one or two points, however, may be emphasised. The **alar spine** of the sphenoid lies just internal to the condyle of the jaw when that structure is in position in the articular part of the glenoid fossa, and it is noteworthy that immediately to the inner side of the alar spine is the commencement of the **osseous Eustachian tube**. The root of the **styloid process** occupies the centre of the interval between the mandibular ramus and the front of the mastoid process.

Anteriorly the arcade formed by the **body** of the **lower jaw** adds greatly to the depth of the hard palate. In this space are lodged the tongue and the structures which form the floor of the mouth. The inner surface of each side of the body of the mandible is traversed by the **internal oblique line** (linea mylo-hyoidea), which commences posteriorly just behind the root of the last molar tooth and runs downwards and forwards towards the symphysis in front.

When the **atlas vertebra** is in articulation with the occipital bone it is well to recognise the relation of its **transverse processes** to the surrounding structures. The extremities of these processes lie in line with the ends of the jugular processes of the occipital bone, and thus come to be placed just internal to and immediately below and slightly in front of the tips of the **mastoid processes**. They can thus be easily felt in the living. Anteriorly they are separated by a short interval from the **styloid processes**, and the **stylo-mastoid foramina** lie immediately in front and slightly to the outer side of their extremities. The student will note that there is no hole in the jugular process of the occipital bone corresponding to the arterial foramen in the transverse process of the atlas through which the vertebral artery passes. The course of this vessel over the upper surface of the posterior arch behind the superior articular processes of the atlas will be seen to coincide with the posterior condylic fossæ and the margins of the foramen magnum immediately internal thereto, where a slight grooving of the edge often indicates the course of the artery. In front the anterior tubercle of the atlas falls in line with the **pharyngeal tubercle** on the under surface of the basi-occipital, and the student must not overlook the fact that the anterior surface of the cervical column does not coincide with the anterior margin of the foramen magnum, but lies nearly half an inch in front of that, in a coronal plane passing immediately in front of the external auditory meatus. Behind, the upper surface of the posterior arch of the atlas overlaps the hinder margin of the foramen magnum, and it is by the apposition of these two surfaces that extension is checked at the occipito-atlantal articulation.

THE SKULL IN SECTION.

By the removal of the skull-cap the interior of the cranial cavity is exposed. The deep surface of the cranial vault is grooved mesially for the **superior longitudinal sinus**, on either side of which are seen numerous depressions for the lodgment of Pacchionian bodies. On holding the bone up to the light, the floor of these little hollows is oftentimes seen to be very thin. A short distance in front of the lambda, and on either side of the saggital suture, are the internal openings of the **parietal foramina**. The inner tables of the frontal and parietal bones are grooved for the meningeal arteries. The principal branch of the **middle meningeal** runs more or less parallel to and at a variable distance behind the line of the coronal suture. Along the bottom of these grooves small foramina may be seen for the passage of nutrient arteries to the bone, and the floor of the longitudinal sinus is likewise pierced by small apertures for the transmission of veins.

The Upper Surface of the Base of the Skull.

Cranial Fossæ.—The upper surface of the base of the skull is divided into three fossæ, of which the cerebrum occupies the anterior and middle, whilst in the posterior is lodged the cerebellum.

The **anterior fossa** is defined posteriorly by the sharp, thin edge of the lesser wings of the sphenoid, which curve outwards and slightly upwards as well as backwards to reach the region of the **pterion** externally. The floor is formed from before backwards, in the middle line, by the upper surface of the ethmoid and the forepart of the body of the sphenoid; laterally it is constituted by the orbital plates

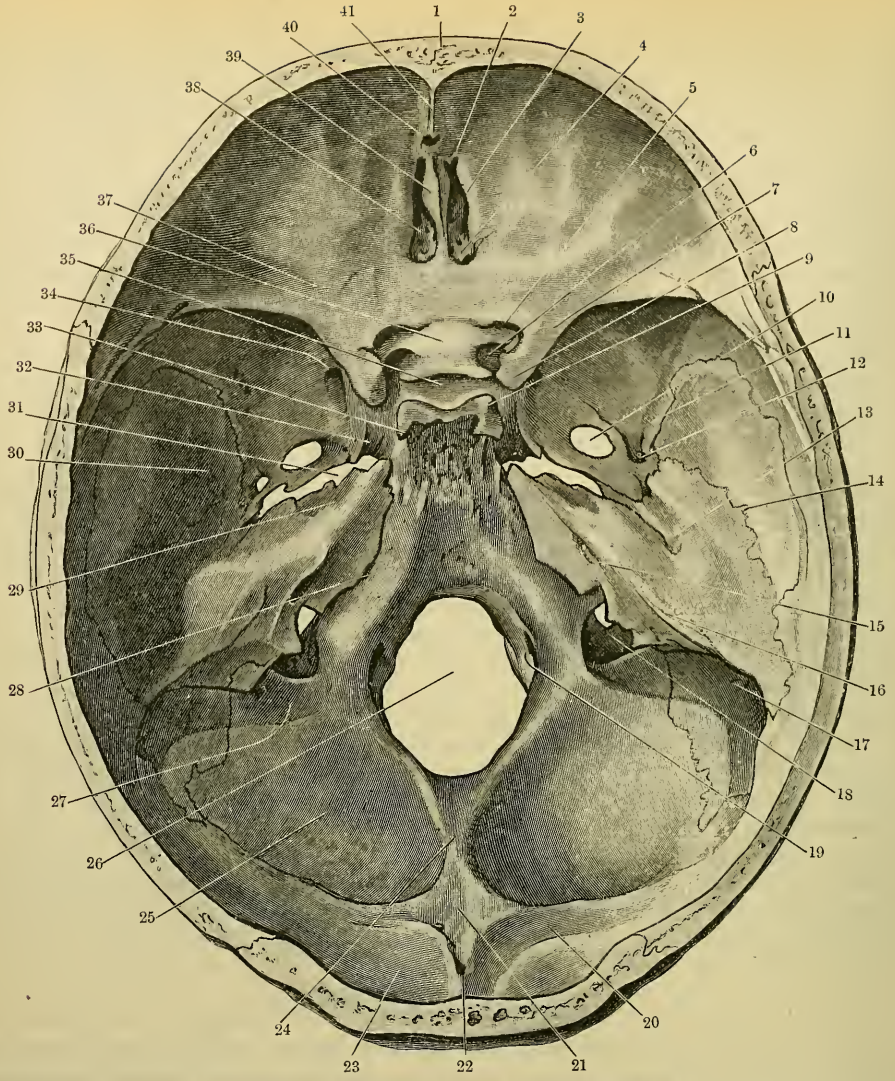


FIG. 122.—BASE OF THE SKULL AS SEEN FROM ABOVE.

1. Frontal bone.
2. Slit for nasal nerve.
3. Anterior ethmoidal foramen.
4. Posterior ethmoidal foramen.
5. Optic foramen.
6. Foramen for internal carotid artery formed by anterior and middle clinoid process.
7. Lesser wing of sphenoid.
8. Anterior clinoid process, in this case united on its inner side to the middle clinoid processes.
9. Posterior clinoid process.
10. Foramen ovale.
11. Groove for middle meningeal artery.
12. Foramen spinosum.
13. Hiatus Fallopii.
14. Line of petro-squamosal suture.
15. Internal auditory meatus.
16. Groove for superior petrosal sinus.
17. Groove for sigmoid part of lateral sinus.
18. Jugular foramen.
19. Anterior condylic foramen.
20. Groove for lateral sinus.
21. Internal occipital protuberance.
22. Ridge for attachment of falx cerebri.
23. Fossa for the lodgment of the occipital lobes of cerebrum.
24. Ridge for the attachment of the falx cerebelli.
25. Fossa for the lodgment of the left cerebellar hemisphere.
26. Foramen magnum.
27. Groove for the sigmoid sinus turning into the jugular foramen.
28. Groove for the inferior petrosal sinus running along the line of suture between the petrous temporal and the basi-occipital.
29. Depression for the Gasserian ganglion.
30. Middle cranial fossa for lodgment of temporal lobe of cerebrum.
31. Foramen lacerum medium.
32. Carotid groove.
33. Dorsum sellæ of sphenoid.
34. Leads into foramen rotundum.
35. Pituitary fossa.
36. Olivary eminence of sphenoid.
37. Anterior cranial fossa for lodgment of frontal lobes of cerebrum.
38. Cribriform plate of ethmoid.
39. Crista galli of ethmoid.
40. Foramen cæcum.
41. Crest for attachment of falx cerebri.

of the frontal and the lesser wings of the sphenoid. On these the under surface of the frontal lobes of the cerebrum rests. In front the fossa is divided mesially by the **frontal crest**, to which the falx cerebri is attached. This is confluent below with the fore part of the **crista galli**, from which, however, it is separated by the **foramen cæcum**, which usually transmits a small vein from the nose. On either side of the crista galli there are grooves which vary considerably in depth and width: therein are lodged the olfactory lobes. The floor and sides of the groove are pierced by numerous foramina; of these the largest number transmit the olfactory nerves to the nasal fossæ. In front an elongated slit, placed on either side of the crista, affords a passage to the nose for the internal nasal nerve and a small branch of the anterior ethmoidal artery which accompanies it. To the outer side of the olfactory groove and the cribriform plate, the anterior fossæ communicate on either side by means of the two **ethmoidal foramina** with the cavities of the orbits. The anterior foramen transmits the internal nasal nerve and the anterior ethmoidal artery; the posterior affords passage to the posterior ethmoidal artery and the small spheno-ethmoidal nerve of Luschka. External to the olfactory groove, the floor of the fossa, which here corresponds to the roof of the orbit, is very thin, as may be seen by holding the skull up to the light; it is convex from side to side, and bears the impress of the convolutions of the under surface of the frontal lobes of the cerebrum which rest upon it. In front and at the side there are a number of vascular grooves for the branches of the anterior and middle meningeal arteries respectively.

The **middle fossa**, which in form may be compared to the wings of a bird united by the body, is bounded in front by the curved thin posterior edge of the lesser wings of the sphenoid; posteriorly, by the line of attachment of the tentorium cerebelli, extending from the **posterior clinoid process** along the superior border of the petrous portion of the temporal bone. The median part of the fossa, which is narrow, corresponds to the **sella turcica** and the **olivary eminence** of the **sphenoid.** It is limited anteriorly by a line connecting the anterior margins of the two optic foramina, and is overhung behind by the **dorsum sellæ.** In this area are lodged the structures which lie within the interpeduncular space on the base of the brain. The floor of the lateral parts of the fossa on each side is formed by the great wing of the sphenoid in front, the squamous part of the temporal bone to the outer side, and the superior surface of the petrous temporal behind. In the hollows so formed the temporal lobes of the cerebrum are lodged. On either side of the olivary eminence are seen the **optic foramina**; these pass into the orbital cavities and transmit the optic nerves and ophthalmic arteries. Immediately behind these openings the anterior and middle clinoid processes are sometimes united, so as to enclose a foramen. Through this the internal carotid artery passes upwards. Leading backwards from this, along the side of the body of the sphenoid, is the **carotid groove**, which turns downwards near the apex of the petrous temporal, to become continuous with the carotid canal, which here opens on the posterior wall of an irregular aperture, placed between the side of the body of the sphenoid and the summit of the petrous temporal, called the **foramen lacerum medium.** Through the inner angle of this opening the carotid artery accompanied by its plexus of veins and sympathetic nerves passes upwards. Running through the fibrous tissue, which in life blocks up this opening, the large superficial petrosal nerve coming from the hiatus Fallopii passes downwards and forwards to reach the posterior orifice of the **Vidian canal**, which is placed on the anterior and inferior border of the foramen lacerum medium. A small meningeal branch of the ascending pharyngeal artery also passes upwards through this foramen. In front and to the outer side of the foramen lacerum, and separated from it by a narrow bar of bone, is the **foramen ovale**; through this pass both roots of the inferior maxillary nerve, the small meningeal artery, and some emissary veins. A little external and posterior to this is the **foramen spinosum** for the transmission of the middle meningeal vessels, together with a recurrent branch from the inferior maxillary nerve. Leading from the external extremity of the foramen lacerum there is a groove which passes outwards, backwards, and slightly upwards on the superior surface of the petrous temporal to end in the **hiatus Fallopii** (a cleft opening into

the **aquæductus Fallopii**), which gives passage to the large superficial petrosal branch derived from the geniculate ganglion on the seventh nerve, together with the small petrosal branch of the middle meningeal artery. Just external to the hiatus Fallopii there is another small foramen for the transmission of the lesser superficial petrosal nerve. Overhung by the posterior border of the lesser wing of the sphenoid is the **sphenoidal fissure**, the cleft which separates the lesser from the great sphenoidal wings, and which opens anteriorly into the hollow of the orbit; through this pass the third, fourth, ophthalmic division of the fifth, and sixth nerves, together with the ophthalmic veins as well as the sympathetic filament to the lenticular ganglion. Just below its inner extremity is the **foramen rotundum** for the passage of the superior maxillary nerve to the spheno-maxillary fossa. Behind this, and between it and the foramen ovale, the **foramen Vesalii** may occasionally be seen, through which a vein passes to reach the pterygoid plexus.

The lateral parts of the middle fossa are moulded in conformity with the convolutions of the temporal lobes, but towards their inner sides the splitting of the dura mater in the region of the cavernous sinus serves to separate the cranial base from the under surface of the cerebrum. As may be seen by transmitted light, the floor of the lateral parts of the fossa is thin as it overlies the **temporal**, **zygomatic**, and **glenoid fossæ**. The grooves for the lodgment of the branches of the middle meningeal artery leading from the foramen spinosum are readily seen; one, coursing backwards a little below the line of the squamoso-parietal suture, is specially well marked. Amongst other features may be noticed the depression for the lodgment of the **Gasserian ganglion** overlying the summit of the petrous temporal; behind and to the outer side of the hiatus Fallopii, the **arcuate eminence**, indicating the position of the superior semicircular canal; and immediately anterior and slightly to the outer side of this the **tegmen tympani**, which roofs in the cavity of the tympanum, the thinness of which can readily be demonstrated if light be allowed to fall through the external auditory meatus.

The **posterior fossa** is larger and deeper than the others. In front it is limited by a line on either side leading backwards and outwards from each **posterior clinoid process** along the superior border of the petrous part of the temporal bone, where externally and posteriorly it becomes confluent with the superior lip of the transverse groove for the **lateral sinus**, ending posteriorly in the middle line at the **internal occipital protuberance**. Along the line thus indicated the process of dura mater called the **tentorium cerebelli**, which roofs in the posterior fossa, is attached. The floor of the fossa, in which the cerebellar lobes, the pons, and medulla are lodged, is formed by the petrous and mastoid portions of the temporal bone, with part of the body of the sphenoid and the basilar portion of the occipital bone wedged in between them. Above the mastoid temporal a small part of the posterior inferior angle of the parietal enters into the constitution of the outer wall of the fossa. Behind and within these the lateral parts and lower portions of the squamous occipital complete the floor. In the middle line the floor of the fossa is pierced by the **foramen magnum**, in which lies the lower part of the medulla, together with its membranes, and through which pass upwards the vertebral arteries and the spinal accessory nerves. On either side of the foramen magnum, and a little in front of a transverse line passing through its centre, is the opening of the **anterior condylic foramen** for the passage of the hypoglossal nerve, a small meningeal branch from the ascending pharyngeal artery and an emissary vein. Overhanging the opening of the anterior condylic foramen there is a thickened rounded bridge of bone, to the outer side of which is placed the irregular opening of the **jugular foramen** (foramen lacerum posterius). The size of this is apt to vary on the two sides, and the lumen is frequently subdivided by a spicule of bone which runs across it; the posterior and external rounded part of the foramen is occupied by the lateral sinus, which here joins the internal jugular vein. A meningeal branch from the ascending pharyngeal or occipital artery also enters the skull through this compartment. The fore and internal part of the foramen is confluent with the groove for the **inferior petrosal sinus**, which turns downwards in front of the spicule above referred to. The interval between the portions of the foramen occupied by the two veins allows the transmission of the glosso-pharyngeal, vagus,

and spinal accessory nerves in order from before backwards. About a quarter of an inch above and to the outer side of the fore part of the foramen jugulare the posterior surface of the petrous portion of the temporal bone is pierced by the **internal auditory meatus**, through which the facial and auditory nerves, together with the pars intermedia of Wrisberg, and the auditory branch of the basilar artery leave the cranial cavity. Behind the jugular foramen and close to the margin of the foramen magnum the opening of the **posterior condylic foramen**, when present, may be seen. This gives passage to a vein which joins the vertebral vein inferiorly. The internal aperture of the **mastoid foramen** is noticed opening into the groove for the lateral sinus, a little below the level of the superior border of the petrous temporal. Through it passes an emissary vein which joins the occipital vein externally; the mastoid branch of the occipital artery also enters the cranial cavity through this foramen.

The posterior fossa is divided into two halves posteriorly by the **internal occipital crest**, to which the falx cerebelli is attached, the floors of the hollows on either side of which are often exceedingly thin and are for the lodgment of the lateral lobes of the cerebellum. The grooves for the following blood sinuses are usually distinct—the **superior petrosal** running along the superior border of the petrous temporal, the **inferior petrosal** lying along the line of suture between the petrous temporal and basilar process of the occipital bone; the **occipital sinus** grooving the internal occipital crest; and the **lateral sinus** curving forwards and outwards from the internal occipital protuberance, across the internal surface of the squamous occipital, to reach the posterior inferior angle of the parietal bone, in front of which it turns downwards and inwards to reach the jugular foramen, describing a sigmoid curve, and grooving deeply the inner surface of the mastoid and posterior aspect of the petrous portions of the temporal bone. Before it terminates at the jugular foramen it again reaches the occipital bone and channels the upper surface of the jugular process of that bone. Slight grooves for meningeal arteries are also seen—some pass upwards, whilst others turn downwards and are occupied by branches from the posterior offsets of the middle meningeal arteries.

Mesial Sagittal Section of the Skull.

Such a section should be made a little to one or other side of the mesial plane, so as to pass through the nasal fossæ lateral to the septum; one-half will then display the nasal septum in position, whilst in the other the outer wall of the nasal fossa of that side will be exposed.

The form of the cranial cavity is, of course, subject to many variations dependent on individual and racial peculiarities. The following details are, however, worthy of note. The hinder border of the foramen magnum (**opisthion**), and consequently the floor of the posterior cranial fossa, occupies the same horizontal plane as the hard palate. The anterior border of the foramen magnum (**basion**) lies a little higher, so that the plane of the foramen is, in the higher races at least, oblique, and is directed downwards and slightly forwards. From the basion a line passing upwards and forwards to reach the suture between the sphenoid and ethmoid passes through the **basi-cranial axis** formed by the basi-occipital, the basi-sphenoid, and the presphenoid. The basi-cranial axis is wedge-shaped on section posteriorly, whilst anteriorly it is of considerable width, and has within it the large sphenoidal air sinus. Its upper surface leads upwards and forwards with a varying degree of obliquity from the basion to the overhanging edge of the dorsum sellæ, in front of which the **pituitary fossa**, the floor of which is quite thin, is well seen in the section.

From the olivary eminence the floor of the anterior fossa follows a more or less horizontal direction, corresponding pretty closely to the level of the axis of the orbital cavity. The roof of the orbit is seen to bulge upwards to a considerable extent into the floor of the anterior fossa; whilst the floor of the middle fossa sinks to a level corresponding to that of the under surface of the basi-cranial axis, where it forms the roof of the posterior nares. The maximum length of the skull is measured from the **glabella** (a point between the superciliary ridges) to the occipital point posteriorly. It is noteworthy that the

maximum occipital point does not necessarily correspond to the external occipital protuberance (**inion**). The greatest vertical height usually corresponds to the distance from the **basion** to the **bregma** (point of union of the sagittal with the coronal suture), though to this rule there are many exceptions. On looking into the posterior fossa the anterior

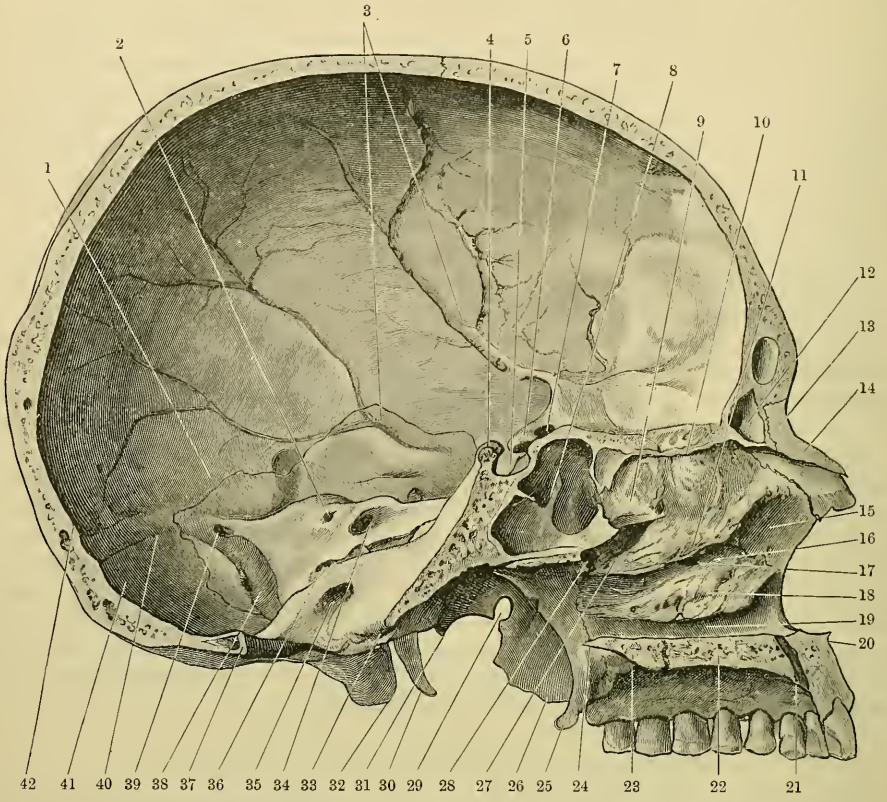


FIG. 123.—INNER ASPECT OF LEFT HALF OF SKULL SAGITTALLY DIVIDED.

1. Suture between parietal and temporal bones.
2. Remains of the subarcuate fossa.
3. Grooves for branches of the middle meningeal artery.
4. Dorsum sellæ.
5. Pituitary fossa.
6. Anterior clinoid fossa.
7. Optic foramen.
8. Sphenoidal sinus.
9. Nasal surface of superior turbinated bone.
10. Cribriform plate of ethmoid.
11. Nasal surface of middle turbinated bone.
12. Frontal sinus.
13. Nasal spine of frontal.
14. Nasal bone.
15. Nasal process of superior maxilla.
16. Middle meatus of nose.
17. Directed towards opening of antrum.
18. Nasal surface of inferior turbinated bone.
19. Inferior meatus of nose.
20. Anterior nasal spine.
21. Anterior palatine canal.
22. Palatal process of superior maxilla.
23. Palatal process of palate bone.
24. Posterior nasal spine.
25. Hamular process of internal pterygoid plate.
26. External pterygoid plate.
27. Superior meatus of nose.
28. Spheno-palatine foramen.
29. Pterygo-spinous ligament almost completely ossified to enclose a foramen.
30. Styloid process of temporal bone.
31. Alar spine of sphenoid.
32. Mastoid process.
33. Basion (mid-point of anterior border of foramen magnum).
34. Internal auditory meatus.
35. Anterior condylic foramen.
36. Leading into jugular foramen.
37. Opisthion (mid-point of posterior border of foramen magnum).
38. Groove for sigmoid sinus.
39. Opening of mastoid foramen.
40. For lateral sinus and attachment of tentorium cerebelli.
41. Fossa for lodgment of cerebellar hemisphere.
42. Internal occipital protuberance.

condylic and jugular foramina and the internal auditory meatus are seen in line, sloping from below upwards. The **internal auditory meatus** lies in a vertical plane, passing through the basion. The grooves for the middle meningeal artery and its branches are very obvious. The anterior groove curves forwards and outwards, and reaching the inner surface of the pterion, passes towards the vertex at a variable distance behind and more or less parallel to the coronal suture. From this grooves pass forwards across the suture

to reach the frontal bone. Another groove curves upwards and backwards a little below the line of the parieto-squamosal suture. From this an upwardly-directed branch radiates on the inner surface of the parietal bone, in the region of the parietal eminence, whilst a lower branch passes backwards some little distance above the lambdoid suture, and gives offsets which curve downwards and inwards over the inner surface of the squamous portion of the occipital bone.

Nasal Fossæ.—In the section through the **nasal fossa** the structures which form its *outer wall* can now be studied. These are—the nasal bone; the nasal process of the superior maxilla; the lachrymal bone; the lateral mass of the ethmoid, comprising the superior and middle turbinated bones; the vertical plate of the palate bone; the inferior turbinated bone; and the mesial surface of the internal pterygoid plate. The *roof* as seen in the section is formed by the nasal and frontal bones, the cribriform plate of the ethmoid, the body of the sphenoid and the sphenoidal turbinals, the sphenoidal process of the palate and the ala of the vomer. The *floor*, which is nearly horizontal from before backwards, is formed by the palatal processes of the superior maxilla and palate bones. On sagittal section the **nasal fossa** appears somewhat triangular in shape with the angles cut off; the base corresponds to the floor; the anterior and posterior nares to the truncated anterior and posterior angles respectively; the superior angle is cut off by the cribriform plate; whilst the sides correspond to the frontal and nasal bones anteriorly, and the sphenoidal turbinals, sphenoidal process of the palate, and the ala of the vomer posteriorly. The cavity is therefore deep towards its middle, but gradually becomes shallower in front and behind where the openings of the nares are situated. The opening of the **anterior naris**, which is of half-heart shape, is larger than that of the **posterior naris**, and is directed forwards and downwards; the opening of the posterior is of rhomboidal form, and slopes backwards and downwards. The **inferior meatus** is the channel which is overhung by the inferior turbinated bone, and its floor is formed by the side-to-side concavity of the upper surface of the hard palate. Opening into it above, under cover of the fore part of the inferior turbinated bone, is the **canal** for the **nasal duct**; whilst its floor is pierced in front near the middle line by the **anterior palatine canal.** The **middle meatus** is the hollow between the middle and inferior turbinated bones; it slopes from above downwards and backwards, and is overhung by the free curved edge of the middle turbinal, beneath which there is a passage called the **infundibulum**, leading upwards and forwards to open superiorly into the frontal sinus, as well as into some of the anterior ethmoidal cells. Under cover of the centre of the middle turbinated bone there is an irregular opening leading into the **maxillary sinus** or antrum of Highmore, and there are frequently independent openings for the middle and some of the anterior ethmoidal cells. The **superior meatus**, about half the length of the middle meatus, is placed between the superior and middle turbinated bones in the back and upper part of the fossa; it receives the openings of the **posterior ethmoidal cells.** Near its posterior extremity the **spheno-palatine foramen** pierces its outer wall, and brings it in relation with the spheno-maxillary fossa. The **sphenoidal sinus** opens on the roof of the nose, above the level of the superior turbinated bone, into a depression called the **spheno-ethmoidal recess.**

Nasal Septum.—If the opposite half of the section in which the osseous **nasal septum** is retained be now studied, it will be seen to be formed by the crests of the superior maxillary and palate bones below, on which rests the vomer, the posterior border of which being free, forms the posterior edge of the nasal septum, which slopes obliquely upwards and backwards towards the under surface of the body of the sphenoid. Here the vomer articulates with the rostrum of the sphenoid. In front of this the vomer articulates with the perpendicular plate of the ethmoid, between which anteriorly there is an angular recess into which the cartilaginous septum fits. Superiorly and anteriorly the osseous septum is completed by the articulation of the perpendicular plate of the ethmoid with the nasal process of the frontal, together with the nasal crest formed by the union of the nasal bones; whilst posteriorly and superiorly the perpendicular plate of the ethmoid articulates with the mesial ethmoidal crest of the sphenoid. In most instances the osseous septum is not perfectly vertical, but is deflected towards one or other side.

Air-sinuses in connexion with the Nasal Fossæ.—Connected with the nasal fossæ are a number of air-sinuses. These are found within the body of the sphenoid, the lateral mass of the ethmoid, the orbital process of the palate bone, the body of the superior maxilla, and the superciliary arch of the frontal bone.

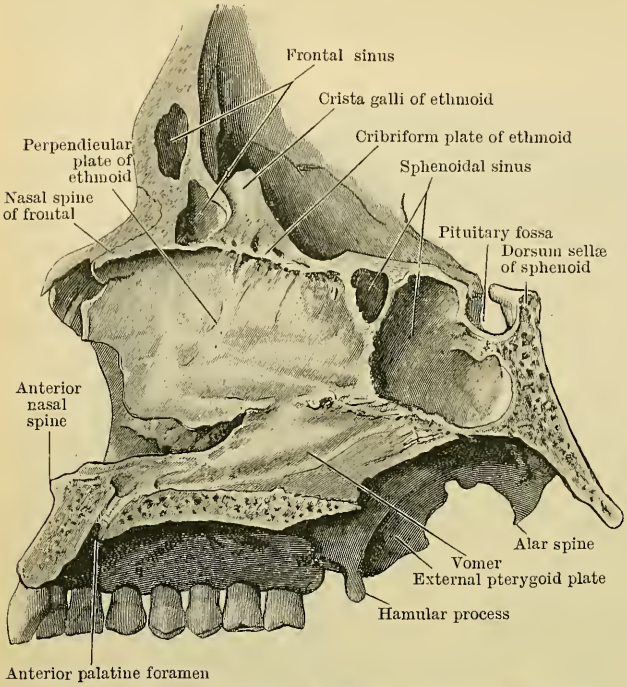


FIG. 124.—NASAL SEPTUM AS SEEN FROM THE LEFT SIDE.

The **sphenoidal sinus**, of variable size, occupies the interior of the body of the sphenoid. In some cases it extends towards the roots of the pterygoid processes. In front it is formed in part by the absorption of the sphenoidal spongy bones, and is divided up into two cavities by a sagittally-placed partition, which, however, is frequently displaced to one or other side. It opens anteriorly into the roof of the nose in the region of the spheno-ethmoidal recess.

The **ethmoidal sinuses** are placed between the lateral aspects of the upper part of the nasal fossæ, and the cavities of the orbit, from which they are separated by thin and papery walls. These air spaces are completed by the articulation of the ethmoid with the superior maxilla, lachrymal, frontal sphenoid, and palate bones, and are divided into three groups—an anterior, middle, and posterior. The latter communicates with the superior meatus; the anterior and middle open either independently or in conjunction with the infundibulum into the middle meatus.

The **sinus** in the orbital process of the **palate bone** either communicates with the sphenoidal sinus, or else assists in closing in some of the posterior ethmoidal cells. Its communication with the nasal fossa is through one or other of these spaces.

The **maxillary sinus** or **antrum** of **Highmore** lies to the outer side of the nasal fossæ, occupying the body of the superior maxilla. Its walls, which are relatively thin, are directed upwards to the orbit, forwards to the face, backwards to the zygomatic and spheno-maxillary fossa, and inwards to the nose. In the latter situation the vertical plate of the palate bone, the uncinate process of the ethmoid, the maxillary process of the inferior turbinated bone, and a small part of the lachrymal bone assist in the formation of the thin osseous partition which separates it from the nasal fossa. The floor corresponds to the alveolar border of the jaw, and differs from the other walls in being stout and thick; it is, however, deeply pitted inferiorly by the alveoli for the teeth. The antrum opens by a narrow orifice into the middle meatus.

The **frontal sinuses** lie, one on either side, between the inner and outer tables of the frontal bone over the root of the nose, and extend outwards under the superciliary arches. The partition which separates them is usually central, though it may be deflected to one or other side. They communicate with the nose through a passage called the **infundibulum**, which opens inferiorly into the fore-part of the middle meatus.

The fact should not be overlooked that the air spaces within the temporal bone, viz. the tympanic cavity and the mastoid air cells, are brought into communication with the naso-pharynx through the Eustachian tubes. For further

details regarding the air sinuses and the mode of their growth, consult the description of the individual bones.

Coronal Sections.

The relations of many parts of the cranium are well displayed in a series of coronal sections.

By sawing off a thin slice from the front of the lower part of the frontal bone above, and carrying the section downwards through the inner wall of the orbit and

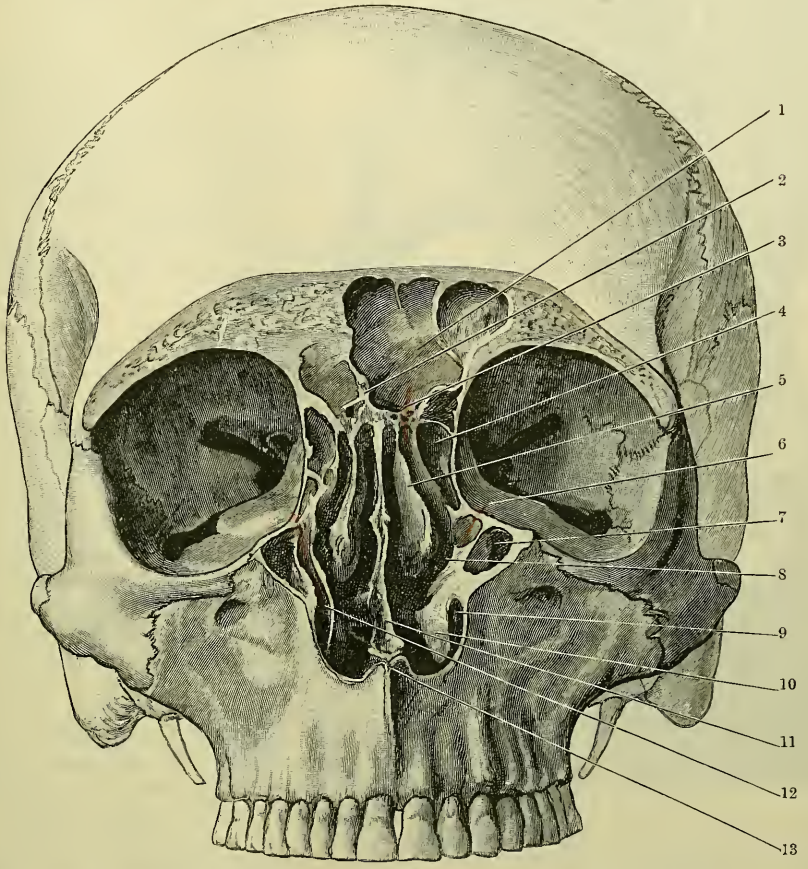


Fig. 125.—Part of the Frontal, Nasal, and Superior Maxillary Bones removed in order to display the Relation of the various Cavities exposed.

1. Frontal sinus.
2. Septum of frontal sinus deflected towards the right.
3. Infundibulum leading from sinus to middle meatus.
4. Anterior ethmoidal air sinuses.
5. Middle turbinated bone.
6. Red line in upper part of osseous canal for nasal duct, laid open throughout its entire length on the right side
7. Cavity of antrum laid open.
8. Middle meatus of nose.
9. Inferior meatus of nose.
10. Inferior turbinated bone.
11. Nasal septum.
12. Canal for nasal duct laid open throughout its entire length.
13. Anterior nasal spine.

the nasal process of the superior maxilla, into the anterior nares below, a number of important relations are revealed (see Fig. 125). In the frontal region the extent and arrangement of the **frontal sinuses** are displayed. The partition between the two sinuses, be it noted, is usually complete and central in position, though it may occasionally be perforated or oblique. The sinuses are hardly ever symmetrical, the right being usually the smaller of the two. (Logan Turner, *Edin. Med. Jour.* 1898.)

The **infundibulum** on either side, leading from the frontal sinus above to the middle meatus below, is seen with the middle turbinated bone internal to it, and the anterior ethmoidal cells to its outer side above. If the section passes through the **canal** for the **nasal duct** the continuity of that channel leading from the orbit above to the inferior

meatus of the nose below is clearly shown. Its inner wall above, by which it is separated from the cavity of the nose, is formed by the thin lachrymal bone; below, it passes under cover of the inferior turbinated bone to open into the fore part of the inferior meatus. It is separated from the antrum externally by a thin lamina of bone. The cavity of the antrum is seen to extend upwards and forwards so as to pass over the outer side as well as slightly in front of the canal for the nasal duct.

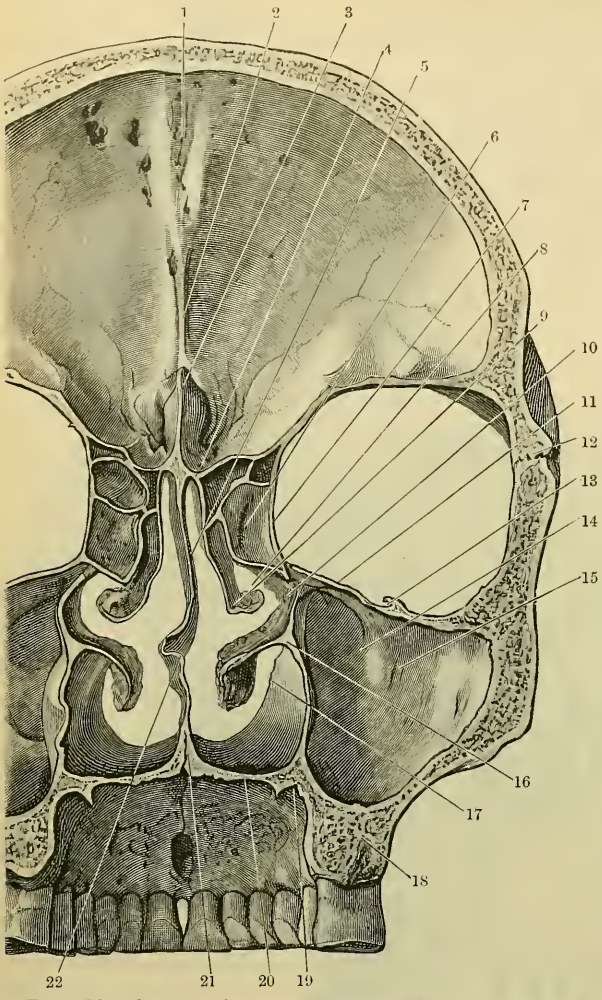


FIG. 126.—CORONAL SECTION PASSING INFERIORLY THROUGH INTERVAL BETWEEN FIRST AND SECOND MOLAR TEETH.

1. Groove for superior longitudinal sinus.
2. Crest for attachment of falx cerebri.
3. Crista galli of ethmoid.
4. Cribriform plate of ethmoid.
5. Perpendicular plate of ethmoid, assisting in the formation of nasal septum.
6. Lateral mass of ethmoid consisting of the ethmoidal cells.
7. Os planum of ethmoid.
8. Middle meatus of nose.
9. Middle turbinated bone.
10. Opening from middle meatus into antrum.
11. Orbital plate of superior maxilla.
12. Fronto-malar suture.
13. Infraorbital groove.
14. Antrum or maxillary sinus.
15. Canal for the anterior dental nerve and vessels exposed.
16. Inferior turbinated bone.
17. Inferior meatus of nose.
18. Alveolar process of superior maxilla.
19. Groove for anterior palatine nerve and vessels.
20. Palatal process of superior maxilla.
21. Maxillary crest forming part of nasal septum.
22. Vomer forming part of nasal septum.

The lower margins of the middle turbinated bones lie pretty nearly on a level with the most dependent parts of the orbital margins, whilst the lower borders of the inferior turbinals are placed a little above the lower margin of the anterior nares on a level with the lowest point of the malo-maxillary suture.

Such a section will reveal any deflection of the nasal septum should it exist, and will also show that but a narrow cleft separates the upper part of the septum, on either side, from the inner surface of the superior turbinals.

The next section (Fig. 126) passes through the fore part of the temporal fossa just behind the external angular process of the frontal bone above; inferiorly it passes through the alveolar process of the upper jaw in the interval between the first and second molar teeth. The cranial, orbital, nasal, and maxillary cavities are all exposed, together with the roof of the mouth.

The **anterior cranial fossa** is deepest in its centre, where its floor is formed by the cribriform plate of the ethmoid; this corresponds to the level of the fronto-malar suture externally. On either side the floor of the fossa bulges upwards, owing to the arching of the roof of the orbit. Of the orbital walls, the external is the thickest and stoutest; the superior, internal, and inferior walls, which separate the orbit from the cranial cavity, the ethmoidal cells, and the antrum, respectively, are all thin. The cavity of the **maxillary sinus** lying to the outer side of the nasal fossæ is well seen. Its roof, which separates it from the orbital cavity, is thin and traversed by the **infraorbital canal**. Its inner wall, with which the inferior turbinal articulates, is very slender, and forms the outer walls of both the middle and inferior meatuses of the nose. Its outer wall is stouter where it arches up to bracket the

zygomatic or malar process. Its floor, which rests upon the upper surface of the alveolar border of the upper jaw, sinks below the level of the hard palate. The fangs of the teeth sometimes project into the floor of the cavity.

The **nasal fossæ** are narrow above, where they lie between the orbital cavities, from which they are separated by the cells within the lateral mass of the ethmoid. The roof which corresponds to the cribriform plate is narrow, and lies between the septum mesially and the lateral masses on either side.

At the level of the orbital floor the nasal fossæ expand laterally, the **middle meatus** running longitudinally in the angle formed by the lateral mass of the ethmoid with the body of the superior maxilla, overhung by the middle turbinated bone. This channel is seen to have the ethmoidal cells superior to it, the orbital cavity above and to the outer side, the antrum externally, whilst its floor is formed by the upper surface of the inferior turbinated bone.

The **inferior meatus**, much more roomy, runs along under cover of the inferior turbinated bone. Externally it is related to the antrum, whilst its floor is formed by the concave superior surface of the hard palate.

The **hard palate** is arched below, whilst its superior surface is concave upwards on either side of the median crest which supports the nasal septum. The sides of the arch below correspond to the inner surfaces of the alveolar processes and fall in line with the outer walls of the nasal fossæ superiorly. The summit of the arch lies a quarter of an inch above the level of the floor of the antrum.

SEXUAL DIFFERENCES IN THE SKULL.

Whilst it is a matter of difficulty, in all cases, to determine with certainty the sex of a skull, the following points of difference are usually fairly characteristic. The female skull is, as a rule, smaller than the male. In point of cranial capacity it averages about a tenth less than the male of corresponding race. It is lighter, smoother as regards the development of its muscular ridges, and possesses less prominent mastoid processes. In the frontal region, the superciliary ridges are less pronounced, and this imparts a thinness and sharpness to the upper orbital margin, which is fairly characteristic, and can best be appreciated by running the finger along that edge of bone. For the same reason, the forehead appears more vertical and the projections of the frontal eminences more outstanding, though it is stated that the frontal and occipital regions are less capacious proportionately than in the male. The vertex in the female is said to be more flattened, and the height of the skull consequently somewhat reduced. In man the edge of the tympanic plate is generally sharp, and divides to form the sheath of the styloid process, whilst in the female the corresponding border is described as being rounder and more tubercular.

Whilst it is true that no one of these differences is sufficiently characteristic to enable us to pronounce with certainty on the matter of sex, it is the case that, taken together, they usually justify us in arriving at a conclusion which, as a rule, may be regarded as fairly accurate. In some instances, however, it is impossible to express any definite opinion.

DIFFERENCES DUE TO AGE.

At birth the face is proportionately small as compared with the cranium, constituting about one-eighth of the bulk of the latter. In the adult the face equals at least half the cranium. About the age of puberty the development and expansion of some of the air-sinuses, more particularly the frontal sinus, lead to characteristic differences in head and face form.

The eruption of the teeth in early life and adolescence enables us to determine the age with fair accuracy. After the completion of the permanent dentition, the wear of the teeth may assist us in hazarding an approximate statement. The condition of the sutures, too, may guide us, synostosis of the coronal and sagittal sutures not as a rule taking place till late in life. Complete obliteration of the synchondrosis between the occipital bone and sphenoid may be regarded as an indication of maturity. In old age the skull usually becomes lighter and the cranial bones thinner. The alveolar borders of the superior and inferior maxillæ become absorbed owing to the loss of the teeth. This gives rise to a flattening of the vault of the hard palate and an alteration in the form of the lower jaw, whereby the mandibular angle becomes more obtuse.

CRANIOLOGY.

The various groups of mankind display in their physical attributes certain features which are more or less characteristic of the stock to which they belong. Craniology deals with these differences so far as they affect the skull. The method whereby these differences are recorded involves the accurate measurement of the skull in most of its details. Such procedure is included under the term craniometry. Here only the outlines of the subject are briefly referred to; for such as desire fuller information on the subject, the works of Broca, Topinard, Flower, and Turner may be consulted.

The races of man display great variations in regard to the size of the skull. Apart altogether from individual differences and the proportion of head-size to body-height, it may be generally assumed that the size of the skull in the more highly civilised races is much in excess of that displayed in lower types. The size of the head is intimately correlated with the development of the brain. By measuring the capacity of that part of the skull occupied by the encephalon, we are enabled to form some estimate of the size of the brain. The **cranial capacity** is determined by filling the cranial cavity with some suitable material and then taking the cubage of its contents. Various methods are employed, each of which has its advantage. The use of fluids, which of course would be the most accurate, is rendered impracticable, without special precautions, owing to the fact that the macerated skull is pierced by so many foramina. As a matter of practice, it is found that leaden shot, glass beads, or seeds of various sorts are the most serviceable. The results obtained display a considerable range of variation. For purposes of classification and comparison, skulls are grouped according to their **cranial capacity** into the following varieties :—

Microcephalic skulls are those with a capacity below 1350 c.c., and include such well-known races as Andamanese, Veddahs, Australians, Bushmen, Tasmanians, etc.

Mesocephalic skulls range from 1350 c.c. to 1450 c.c., and embrace examples of the following varieties : American Indians, Chinese, some African Negroes.

Megacephalic skulls are those with a capacity over 1450 c.c., and are most commonly met with in the more highly civilised races : Mixed Europeans, Japanese, Eskimo, etc.

Apart from its size, the form of the cranium has been regarded as an important factor in the classification of skulls; though whether these differences in shape have not been unduly emphasised in the past is open to question.

The relation of the breadth to the length of the skull is expressed by means of the **cephalic index** which records the proportion of the maximum breadth to the maximum length of the skull, assuming the latter equal 100, or—

$$\frac{\text{Max. breadth} \times 100}{\text{Max. length}} = \textbf{Cephalic index.}$$

The results are classified into three groups :—

1. **Dolichocephalic**, with an index below 75 : Australians, Kaffirs, Zulus, Eskimo, Fijians.
2. **Mesaticephalic**, ranging from 75 to 80 : Europeans (mixed), Chinese, Polynesians (mixed).
3. **Brachycephalic**, with an index over 80 : Malays, Burmese, American Indians, Andamanese.

In order to provide for uniformity in the results of different observers, some system is necessary by which the various points from which the measurements are taken must correspond. Whilst there is much difference in the value of the measurements insisted on by individual anatomists, all agree in endeavouring to select such points on the skull as may be readily determined, and which have a fairly fixed anatomical position. The more important of these "fixed points" are included in the subjoined table :—

Nasion.—The middle of the naso-frontal suture.

Glabella.—A point midway between the two superciliary ridges.

Ophryon.—The central point of the narrowest transverse diameter of the forehead, measured from one temporal line to the other.

Inion.—The external occipital protuberance.

Maximum Occipital Point.—The point on the occipital squama in the sagittal plane most distant from the glabella.

Opisthion.—The middle of the posterior margin of the foramen magnum.

Basion.—The middle of the anterior margin of the foramen magnum.

Bregma.—The point of junction of the coronal and sagittal sutures.

Alveolar Point.—The centre of the anterior margin of the upper alveolar margin.

Subnasal Point.—The middle of the inferior border of the anterior nasal aperture at the centre of the nasal spine.

Vertex.—The summit of the cranial vault.

Obelion.—A point over the sagittal suture, on a line with the parietal foramina.

Lambda.—The meeting-point of the sagittal and lambdoid sutures.

Pterion.—The region of the antero-lateral fontanelle where the angles of the frontal, parietal, squamous temporal, and alisphenoid lie in relation to one another. As a

rule, the sutures are arranged like the letter H, the parietal and alisphenoid separating the frontal from the squamous temporal. In other cases the form of the suture is like an X; whilst in a third variety the frontal and squamous temporal articulate with each other, thus separating the alisphenoid from the parietal.

Asterion is the region of the postero-lateral fontanelle where the lambdoid, parieto-mastoid, and occipito-mastoid sutures meet.

Stephanion.—The point where the coronal suture crosses the temporal crest.

Dacryon.—The point where the vertical lachrymo-maxillary suture meets the fronto-nasal suture at the inner angle of the orbit.

Jugal Point.—Corresponds to the angle between the vertical border and the margin of the zygomatic process of the malar bone.

Gonion.—The outer side of the angle of the inferior maxilla.

The measurements of the length of the skull may be taken between a variety of points—the nasion, glabella, or ophryon in front, and the inion or maximum occipital point behind. Or the maximum length alone may be taken without reference to any fixed points. In all cases it is better to state precisely where the measurement is taken. The maximum breadth of the head is very variable as regards its position; it is advisable to note whether it occurs above or below the parieto-squamosal suture. The inter-relation of these measurements as expressed by the cephalic index has been already referred to. The width of the head may also be measured from one asterion to the other, **biasterionic width**, or by taking the **bistephanic diameter.**

The height of the cranium is usually ascertained by measuring the distance from the basion to the bregma. The relation of the height to the length may be expressed by the **height** or **vertical index**, thus—

$$\frac{\text{Height} \times 100}{\text{Length}} = \textbf{Vertical index.}$$

Skulls are classified in accordance with the relations of length and height as follows:—

Tapeinocephalic index below 72.
Metriocephalic index between 72 and 77.
Akrocephalic index above 77 (Turner).

or

Chamæcephalic index up to 70.
Orthocephalic index from 70·1 to 75.
Hypsicephalic index 75·1 and upwards (Kollmann, Ranke, and Virchow).

The **horizontal circumference** of the cranium, which ranges from 450 mm. to 550 mm., is measured around a plane cutting the glabella or ophryon anteriorly, and the maximum occipital point posteriorly. The **longitudinal arc** is measured from the nasion in front to the opisthion behind; if to this be added the basi-nasal length and the distance between the basion and the opisthion, we have a record of the vertico-mesial circumference of the cranium. This may further be divided by measuring the lengths of the frontal, parietal, and occipital portions of the superior longitudinal arc. In this way the relative proportions of these bones may be expressed.

The measurements of the skeleton of the face are more complex, but, on the whole, of greater value than the measurements of the cranium. It is in the face that the characteristic features of race are best observed, and it is here that osseous structure most accurately records the form and proportions of the living.

The form of the face varies like that of the cranium in the relative proportions of its length and breadth. Generally speaking, a dolichocephalic cranium is associated with a long face, whilst the brachycephalic type of head is correlated with a rounder and shorter face. This rule, however, is not universal, and there are many exceptions to it.

The determination of the facial index varies according to whether the measurements are made with or without the mandible in position. In the former case the length is measured from the ophryon or nasion above to the mental tubercle below, and compared with the maximum bizygomatic width. This is referred to as the **total facial index**, and is obtained by the formula—

$$\frac{\text{Ophryo-mental length} \times 100}{\text{Bizygomatic width}} = \textbf{Total facial index.}$$

More usually, however, owing to the loss of the lower jaw, the proportions of the face are expressed by the **superior facial index.** This is determined by comparing the ophryo-alveolar or naso-alveolar length with the bizygomatic width, thus—

$$\frac{\text{Ophryo-alveolar length} \times 100}{\text{Bizygomatic width}} = \textbf{Superior facial index.}$$

The terms **dolichofacial** or **leptoprosope** and **brachyfacial** or **chamœprosope** have been employed to express the differences thus recorded.

Uniformity in these measurements, however, is far from complete since many anthropologists compare the width with the length = 100.

The proportion of the face-width to the width of the calvaria is roughly expressed by the use of the terms **cryptozygous** and **phænozygous** as applied to the skull. In the former case the zygomatic arches are concealed, when the skull is viewed from above, by the overhanging and

projection of the sides of the cranial box; in the latter instance, owing to the narrowness of the calvaria, the zygomatic arches are clearly visible.

The projection of the face, so characteristic of certain races (Negroes for example), may be estimated on the living by measuring the angle formed by two straight lines, the one passing from the middle of the external auditory meatus to the lower margin of the septum of the nose; the other drawn from the most prominent part of the forehead above to touch the incisor teeth below. The angle formed by the intersection of these two lines is called the **facial angle** (Camper), and ranges from 62° to 85°. The smaller angle is characteristic of a muzzle-like projection of the lower part of the face. The larger angle is the concomitant of a more vertical profile. The degree of projection of the upper jaw in the macerated cranium is most commonly expressed by employing the **gnathic** or **alveolar index** of Flower. This records the relative proportions of the basi-alveolar and basi-nasal lengths, the latter being regarded as = 100, thus—

$$\frac{\text{Basi-alveolar length} \times 100}{\text{Basi-nasal length}} = \textbf{Gnathic index.}$$

The results are conveniently grouped into three classes:—

Orthognathous, index below 98: including mixed Europeans, ancient Egyptians, etc.
Mesognathous, index from 98 to 103: Chinese, Japanese, Eskimo, Polynesians (mixed).
Prognathous, index above 103: Tasmanians, Australians, Melanesians, various African Negroes.

Unfortunately, however, little reliance can be placed on the results obtained by this method, since it takes no account of the proportion of the third or facial side of the gnathic triangle. For a further discussion of this matter see Thomson and MacIver, *Races of the Thebaid* (Oxford: Clarendon Press, 1905).

The form of the nasal aperture in the macerated skull is of much value from an ethnic standpoint, as it is so intimately associated with the shape of the nose in the living. The greatest width of the nasal aperture is compared with the nasal height (measured from the nasion to the lower border of the nasal aperture) and the **nasal index** is thus determined:—

$$\frac{\text{Nasal width} \times 100}{\text{Nasal height}} = \textbf{Nasal index.}$$

Skulls are—

Leptorhine, with a nasal index below 48: as in mixed Europeans, ancient Egyptians, American Indians, etc.
Mesorhine, with an index ranging from 48 to 53: as in Chinese, Japanese, Malays, etc.
Platyrhine, with an index above 53: as in Australians, Negroes, Kaffirs, Zulus, etc.

The form of the orbit varies considerably in different races, but is of much less value from the standpoint of classification. The **orbital index** expresses the proportion of the orbital height to the orbital width, and is obtained by the following formula:—

$$\frac{\text{Orbital height} \times 100}{\text{Orbital width}} = \textbf{Orbital index.}$$

The orbital height is the distance between the upper and lower margins of the orbit at the middle; whilst the orbital width is measured from a point where the ridge which forms the posterior boundary of the lachrymal groove meets the fronto-lachrymal suture (Flower), or from the dacryon (Broca) to the most distant point from these on the anterior edge of the outer border of the orbit.

The form of the orbital aperture is referred to as—

Megaseme, if the index be over 89;
Mesoseme, if the index be between 89 and 84;
Microseme, if the index be below 84.

The variations met with in the form of the palate and dentary arcade may be expressed by the **palato-maxillary index** of Flower. The length is measured from the alveolar point to a line drawn across the hinder borders of the superior maxillary bones, whilst the width is taken between the outer borders of the alveolar arch immediately above the middle of the second molar tooth. To obtain the index, the following formula is employed:—

$$\frac{\text{Palato-maxillary width} \times 100}{\text{Palato-maxillary length}} = \textbf{Palato-maxillary index.}$$

For purposes of classification Turner has introduced the following terms:—

Dolichuranic, index below 110.
Mesuranic, index between 110 and 115.
Brachyuranic, index above 115.

As is elsewhere stated (p. 183), the size of the teeth has an important influence on the architecture of the skull. Considered from a racial standpoint, the relative size of the teeth to

the length of the cranio-facial axis has been found by Flower to be a character of much value. The dental length is taken by measuring the distance between the anterior surface of the first premolar and the posterior surface of the third molar of the upper jaw.

To obtain the **dental index** the following formula is used :—

$$\frac{\text{Dental length} \times 100}{\text{Basi-nasal length}} = \textbf{Dental index.}$$

Following the convenient method of division adopted with other indices, the dental indices may be divided into three series, called respectively—

Microdont, index below 42 : including the so-called Caucasian or white races.
Mesodont, index between 42 and 44 : including the Mongolian or yellow races.
Megadont, index above 44 : comprising the black races, including the Australians.

Many complicated instruments have been devised to take the various measurements required, but for all practical purposes the calipers designed by Flower or the *compas glissière* of Broca are sufficient.

As an aid to calculating the indices, the tables published in the *Osteological Catalogue of the Royal College of Surgeons of England*, Part I., Man. ; *Index-Tabellen zum Anthropometrischen Gebrauche*, C. M. Furst, Jena, 1902 ; or the index calculator invented by Dr. Waterston will be found of much service in saving time.

DEVELOPMENT OF THE CHONDRO-CRANIUM AND MORPHOLOGY OF THE SKULL.

As has been already stated (p. 24), the chorda dorsalis extends forwards to a point immediately beneath the anterior end of the mid-brain. In front of this the head takes a bend so that the large fore-brain overlaps the anterior extremity of the notochord. At this stage of development the cerebral vesicles are enclosed in a membranous covering derived from the mesenchyme surrounding the notochord ; this differentiated mesodermal layer is called the primordial membranous cranium. From it the meninges which invest the brain are derived. In lower vertebrates this membranous capsule becomes converted into a thick-walled cartilaginous envelope, the primordial cartilaginous cranium. In mammals, however, only the basal part of this capsule becomes chondrified, the roof and part of the sides remaining membranous. In considering the chondrification of the skull in mammals, it must be noted that part only of the base is traversed by the notochord, viz. that portion which extends from the foramen magnum to the dorsum sellæ of the sphenoid. It is, therefore, conveniently divided into two parts—one posterior, surrounding the notochord, and hence called **chordal**, and one in front, into which the notochord does not extend, and hence termed **prechordal**. These correspond respectively to the vertebral and evertebral regions of Gegenbauer. In the chordal region a pair of elongated cartilages, called the **parachordal cartilages**, appear one on either side of the notochord ; these soon all but completely envelop the chorda, and expand so as to form the basilar or occipital plate, which ossifies later to form the basilar process of the occipital bone, and the dorsum sellæ of the sphenoid. By backward extension from the occipital plate on either side and around the foramen magnum the cartilaginous ex-occipitals and supra-occipitals are also formed. In the prechordal region two curved strips of cartilage, the **trabeculæ cranii** of Rathke, arise and pass forwards from the anterior extremity of the notochord, one on either side of the cranio-pharyngeal canal. In front these trabeculæ spread out and ultimately fuse to form the **ethmoidal plate**, which constitutes the fore part of the chondro-cranium. Posteriorly the trabeculæ unite with the basilar plate and thus surround the cranio-pharyngeal canal, the lumen of which is subsequently closed to form the floor of the pituitary fossa, in which rests the hypophysis cerebri. Owing to the presence of the nasal capsules, the fore-part of the ethmoidal plate becomes differentiated into an **ethmo-vomerine region**, from which the nasal septum and its associated cartilages are derived, whilst the remainder of the ethmoidal plate by expansion and subsequent ossification develops to form the pre-sphenoid, the orbito-sphenoids, and the ali-sphenoids, which latter assist in completing the orbital cavity for the lodgment of the eyeball. The membranous ear capsules which lie lateral to the parachordal cartilages become chondrified and form the **cartilaginous ear capsules**. These soon unite with the lateral aspects of the basilar plate, but are separated in front from the cartilaginous alisphenoid of the ethmoidal plate by a membranous interval, which is subsequently occupied by the squamosal, a bone of dermic origin. This disappearance of the cartilage under the squamosal was regarded by Parker as the diagnostic mark of the mammalian chondro-cranium.

From the ventral surface of this cartilaginous platform—formed, as described, by the

union of the trabeculæ, parachordal cartilages, and cartilaginous ear capsules—is suspended the cartilaginous framework of the visceral arches, which play so important a part in the development of the face, an account of which is elsewhere given (p. 36).

A consideration of the facts of comparative anatomy and embryology appears to justifiy the assumption that the mammalian skull is of two-fold origin—that, in fact, it is composed of two envelopes, an outer and an inner, primarily distinct, but which in the process of evolution have become intimately fused together. The inner, called the primordial skull, is that which has just been described, and consists of the chondro-cranium and the branchial skeleton. The outer, which is of dermic origin, includes the bones of the cranial vault and face which are developed in membrane. This secondary skull, which first appears in higher fishes as ossified dermal plates overlying the primary skull, acquires a great importance in the mammalia, as owing to the expansion of the

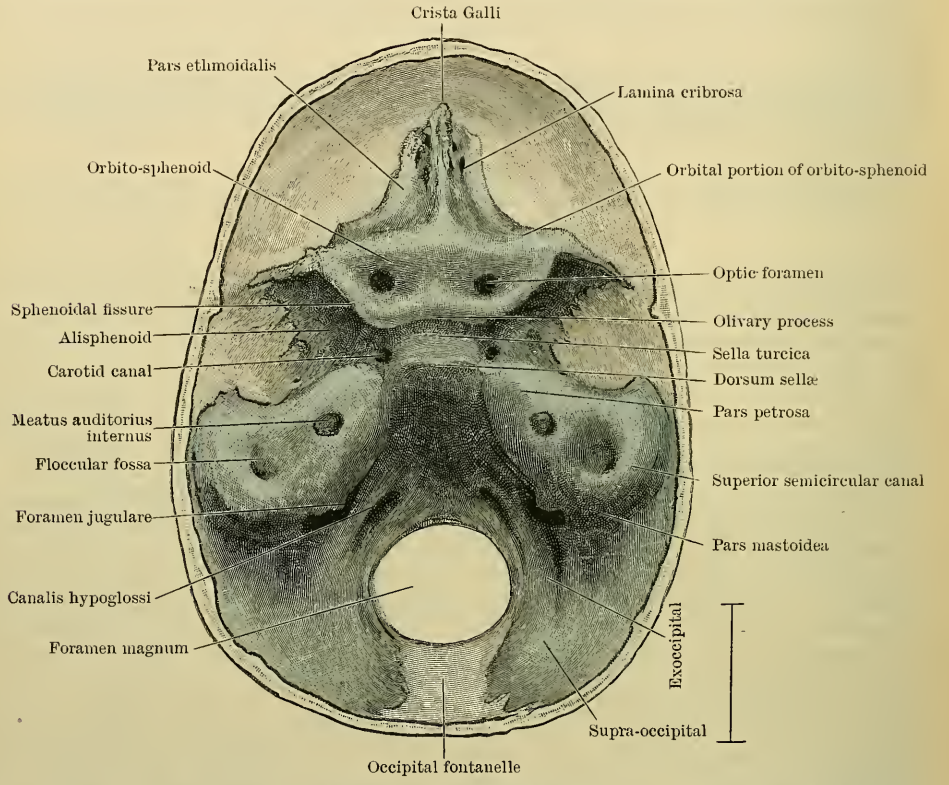


Fig. 127.—View of the Chondro-Cranium of a Human Fœtus 5 cm. in length from Vertex to Coccyx (about the middle of the third month); the cartilage is coloured blue. The line to the right of the drawing shows the actual size.

brain and the progressive reduction of the chondro-cranium, these dermal bones become engrafted on and incorporated with the primordial skull, and act as covering bones to the cavities of the cranium and face; for it may be well to point out that these dermal or membrane bones are not necessarily external in position, as over the cranial vault, but also develop in the tissues underlying the mucous membrane of the cavities of the face.

Advantage is taken of this difference in the mode of development of the bones of the skull to classify them according to their origin into **cartilage** or **primordial bones**, and **membrane** or **secondary bones**. These differences in the growth of the bone must not be too much insisted on in determining the homologies of the bones of the skull, as it is now generally recognised that all bone is of membranous origin, and that whilst in some cases cartilage may become calcified, it never undergoes conversion into true bone, but is replaced by ossific deposit derived from a membranous source. In the subsequent growth of the skull parts of the cartilaginous cranium persist as the septal and alar cartilages of the nose, whilst for a considerable period the basi-sphenoid and basi-occipital are still united by cartilage. The cartilage also which blocks the foramen lacerum medium may be regarded as a remnant of the chondro-cranium.

Till two years after birth there are membranous intervals between the edges and

angles of the bones of the cranial vault. These are termed the **fontanelles**. Normally they are six in number, and correspond in the adult to the position of the bregma and lambda in the middle line and the pterion and asterion on either side. The **anterior** or **bregmatic fontanelle** is diamond-shaped, and corresponds to the converging angles of the parietals and two halves of the frontal bone. The **posterior fontanelle** is triangular in form, and lies between the two parietals and the summit of the occipital squama. The **antero-lateral fontanelle** lies between the contiguous margins of the frontal, parietal, squamous temporal, and great wing of the sphenoid, whilst the **postero-lateral fontanelle** is situated between the adjacent borders of the parietal, occipital, and mastoid portion of the temporal. The term occipital fontanelle is applied to a membranous interval which occurs in the fœtal condition posterior to the foramen magnum, and between the lateral halves of the cartilaginous supra-occipital. Its persistence accounts for the occasional occurrence of a cerebral meningocele.[1]

Whilst in many instances the primordial and secondary bones remain distinct in the fully-developed condition, they sometimes fuse to form complex bones, such as the temporal and sphenoid (see pp. 120 and 127).

Various theories have been advanced to account for the mode of formation of the skull. The earliest of these was called the vertebrate theory, which assumed that the cranium was built up of a series of modified vertebræ, the centra of which corresponded to the basi-cranial axis, whilst the neural arches were represented by the covering bones of the cranium. In view of the more recent researches regarding the composite origin of the skull above referred to, this theory was necessarily abandoned. It gave way to the suggestion of Gegenbauer that the primordial cranium has arisen by the fusion of several segments equivalent to vertebræ, the number of which he determined by noting the metameric arrangement of the cranial nerves, of which he concluded there were nine pairs, arranged much like spinal nerves, both as to their origin and distribution. The olfactory and optic nerves, though frequently referred to as cranial nerves, are excluded, since from the nature of their development they are to be regarded as metamorphosed parts of the brain itself. Gegenbauer therefore assumed that that portion of the cranial base which is traversed by the nine pairs of segmentally arranged cranial nerves must be formed by the fusion of nine vertebral segments; and as the region where the nerves escape corresponds to the part of the chondro-cranium traversed by the notochord, he calls it the vertebral portion of the cranial base, in contradistinction to the trabecular or non-vertebral part which lies in front. This latter he regards as a new formation adapted to receive the greatly-developed brain and afford protection to the organs of sight and smell.

As has been pointed out by Hertwig, there is an essential difference between the development of the axial cartilaginous skeleton of the trunk and head. The former becomes segmented into distinct vertebræ alternating with intervertebral ligaments; whilst the latter, in order to attain the rigidity necessary in this part of the skeleton, is never so divided. It follows from this that the original segmentation of the head is only expressed in three ways, viz. in the appearance of several primitive segments (myotomes), in the arrangement of the cranial nerves, and in the fundament of the visceral skeleton (visceral arches). According to Froriep the mammalian occipital corresponds to the fusion of four vertebræ, and there is some reason for supposing that in some classes of vertebrates the occipital region of the primordial cranium is increased by fusion with the higher cervical segments.

The form of skull characteristic of man is dependent on the large proportionate development of the cranial part, which contains the brain, and the reduction in size of the visceral part (face), which protects the organs of special sense. This leads to a decrease in the mass and projection of the jaws, as well as a reduction in the size of the teeth. Associated with the smaller mandible there is a feebler musculature, with a reduced area of attachment to the sides of the skull. In this way the disappearance of the muscular crests and fossæ, so characteristic of lower forms, is accounted for. At the same time the fact that the skull is poised on the summit of a vertical column, leads to important modifications in its structure. The disposition of parts is such that the occipito-vertebral articulation is so placed that the fore and hind parts of the head nearly balance each other, thus obviating the necessity for a powerful muscular and ligamentous mechanism to hold the head erect.

Another noticeable feature in connexion with man's skeleton is the prolonged period during which growth may occur before maturity is reached; this is associated with a more complete consolidation of the skull, since bones, which in lower forms remain throughout

[1] For further information regarding anomalous conditions of the fontanelles and the occurrence of Wormian or sutural ossicles, see F. Frassetto, *Ann. des Sci. Nat. Zool.* 8e sér. xviii. 1903.

life distinct, are in man fused with each other, as exemplified in the case of the presphenoid and postsphenoid, the occipital and the interparietal, to mention one or two instances among many. It is noteworthy, however, that during ontogeny the morphological significance of these bones is clearly demonstrated by their independent ossification.

The points of exit of the various cranial nerves remain remarkably constant, and in their primitive condition serve to suggest the segmental arrangement of the cartilaginous chondro-cranium already referred to. Owing to the very great modifications which the mammalian skull has undergone in the process of its evolution, it may be pointed out that the passage of the nerves through the dura mater—a derivative, the readers may be reminded, of the primordial membranous cranium (see *ante*)—alone represents the primitive disposition of the nerves. Their subsequent escape through the bony base is a later and secondary development. In some cases the two, membranous or primary and the osseous or secondary foramina, correspond. In other instances the exit of the nerves through the dura mater does not coincide with the passage through the bone.

Of interest in this connexion it may be pointed out that the foramina and canals which traverse the skull are either situated in the line of suture between adjacent bones or in the line of fusion of the constituent parts of which the bone pierced is made up. For example, the sphenoidal fissure is situated between the orbito and alisphenoids; the anterior condylic between the basi and exoccipitals; the jugular between the petrous, basi, and exoccipital; the optic between the orbito-sphenoid and the presphenoid; the Vidian between the alisphenoid, internal pterygoid plate, and the lingula.

THE BONES OF THE UPPER EXTREMITY.

The Clavicle.

The **clavicle** (clavicula), or collar bone, one of the elements in the formation of the shoulder girdle, consists of a curved shaft, the extremities of which are enlarged. The inner end, since it articulates with the sternum, is called the sternal end; the outer extremity, from its union with the acromion process of the scapula, is known as the acromial end.

The **sternal end** (extremitas sternalis) is enlarged, and rests upon the meniscus

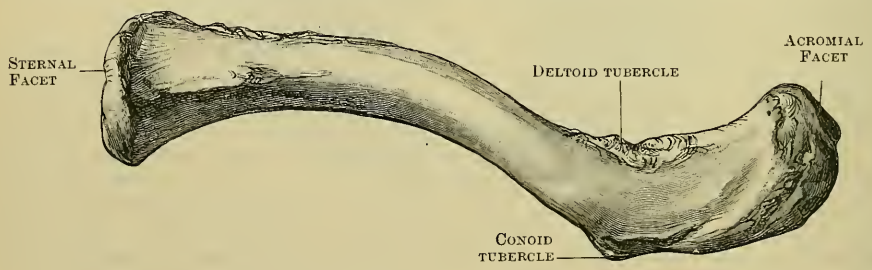


Fig. 128.—Right Clavicle as seen from Above.

of fibro-cartilage which is interposed between it and the clavicular facet on the upper and external angle of the manubrium sterni. It is also supported by a small part of the inner end of the cartilage of the first rib. Its *articular surface*, usually broader from above downwards than from side to side, displays an antero-posterior convexity, whilst tending to be slightly concave in a vertical direction. The edge around the articular area which serves for the attachment of the capsule of the sterno-clavicular articulation is sharp and well defined, except below where it is rounded.

The **shaft** is so curved that its anterior outline is convex in its inner two-thirds, whilst concave in the outer third of its length. Rounded or prismatic in form towards its sternal extremity, the shaft becomes compressed and flattened towards its outer end. Its *superior surface*, which is smooth and subcutaneous throughout its whole length, is directed upwards and forwards; the *inferior surface* is inclined downwards and backwards. The *anterior border*, which separates the upper from the under surface in front, is rough and tubercular towards its inner end for the attachment of the clavicular fibres of the pectoralis major, whilst externally

where it becomes continuous with the anterior margin of the acromial end, it is better defined, and bears the imprint of the origin of the fibres of the deltoid muscle; here, not uncommonly, a projecting spur of bone, called the **deltoid tubercle**, may be seen. The *posterior border* is broad internally, where it is lipped

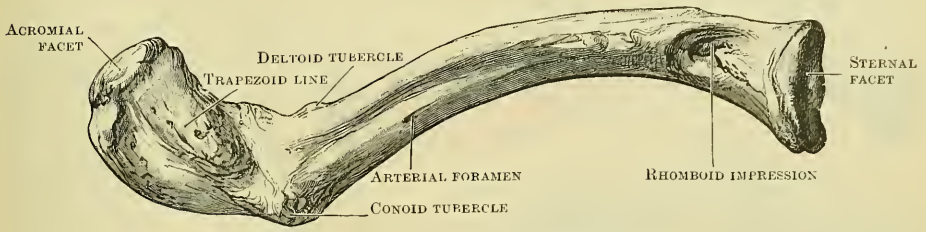


FIG. 129.—RIGHT CLAVICLE AS SEEN FROM BELOW.

superiorly to furnish an attachment for the clavicular fibres of the sterno-mastoid muscle; behind and below this the sterno-hyoid and sterno-thyroid muscles are attached to the bone. Externally, the posterior border becomes more rounded, and is confluent with the posterior edge of the acromial end at a point where there is a marked outgrowth of bone from its under surface, **the conoid tubercle** (tuberositas coracoidea). Into the outer third of this border are inserted the upper and anterior fibres of the trapezius muscle. The *inferior surface* of the shaft close to the sternal end is marked by an irregular elongated impression (tuberositas costalis), often deeply pitted, for the attachment of the rhomboid ligament, which unites it to the cartilage of the first rib. External to this the shaft is channelled by a groove which terminates close to the conoid tubercle; into this groove the subclavius muscle is inserted.

The **acromial end** of the bone is flattened and compressed from above downwards, and expanded from before backwards; its anterior edge is sharp and well defined, and gives attachment to the deltoid muscle, which also spreads over part of its upper surface. Its posterior margin is rougher and more tubercular, and provides a surface for the insertion of the trapezius. The area between these two muscular attachments is smooth and subcutaneous. The outer edge of this forward-turned part of the bone is provided with an oval facet (facies articularis acromialis) for articulation with the acromion process of the scapula; the margins around this articular area serve for the attachment of the capsule of the joint. The inferior surface of the acromial end of the bone is traversed obliquely from behind forwards and outwards by a rough ridge or line called the **trapezoid** or **oblique ridge**. The posterior extremity of this ridge, as it abuts on the posterior border of the bone, forms a prominent process, the **conoid tubercle** (tuberositas coracoidea); to each of these, respectively, are attached the trapezoid and conoid portions of the coraco-clavicular ligament.

Nutrient Foramina.—The foramina for the larger nutrient vessels, of which there may be one or two directed outwards, are usually found about the middle of the posterior border, or it may be opening into the floor of the groove for the subclavius muscle.

Architecture.—The shaft consists of an outer layer of compact bone, thickest towards the centre, but gradually thinning towards the extremities, the investing envelope of which consists merely of a thin shell. Within the shaft the cancellous tissue displays a longitudinal striation, which internally assumes a more cellular appearance. At the acromial end the general arrangement of the fibres resembles the appearance of the sides of a Gothic arch. The curves of the bone impart an elasticity to it, which is of much service in reducing the effects of the shocks to which it is so frequently subjected.

Variations.—The clavicles of women are more slender, less curved, and shorter than those of men. In the latter the bone is so inclined that its outer end lies slightly higher or on the same level with the sternal end. In women the bone usually slopes a little downward and outward. The more pronounced curves of some bones are probably associated with a more powerful development of the pectoral and deltoid muscles, a circumstance which also affords an explanation of the differences usually seen between the right and left bones, the habitual use of the right upper limb reacting on the form of the bone of that side. The influence of muscular action, however, does not wholly account for the production of the curves of the bone, since the bone has been shown to display its characteristic features in cases where there has been defective

development or absence of the upper limb (Reynault). Partial or complete absence of the clavicle has been recorded. W. S. Taylor exhibited an interesting case of this kind at the Clinical Society of London, October 25, 1901.

Ossification.—Phylogenetically of dermic origin, the clavicle in man is remarkable in commencing to ossify before any other bone in the body; this occurs as early as the fifth or sixth week of fœtal life. The **primitive centre** from which the shaft and outer extremity are developed appears prior to the formation of any cartilaginous matrix; and it is not till a later stage that cartilage plays a part in the development of the bone by assisting in the growth of its extremities.

Fig. 130.—Ossification of the Clavicle.

A **secondary centre** or **epiphysis** appears at the sternal end about the age of twenty or later, and fusion rapidly occurring between it and the shaft, ossification is completed at the age of twenty-five or thereabouts.

The Scapula.

The **scapula** (scapula), shoulder blade or blade bone, is of triangular shape and flattened form. It has two surfaces, ventral and dorsal. From the latter there springs a triangular process called the **spine**, which ends externally in the **acromion**; whilst from its superior border there arises a beak-like projection called the **coracoid** process.

The **body** of the bone, which is thin and translucent, except along its margins and where the spine springs from it, has three borders and three angles. Of these borders the *internal* or *vertebral* (margo vertebralis) is the longest; it stretches from the superior angle above to the inferior angle below. Of curved or somewhat irregular outline, it affords a narrow surface for the insertion of the levator anguli scapulæ, rhomboideus minor, and rhomboideus major muscles.

The *superior border* (margo superior), which is thin and sharp, is the shortest of the three. It runs from the superior angle towards the root of the coracoid process, before reaching which, however, it is interrupted by the **suprascapular notch** (incisura scapulæ), which lies immediately to the inner side of the base of that process. This notch, which is converted into a foramen by a ligament, or occasionally by a spicule of bone, transmits the suprascapular nerve. Attached to the superior border, close to the notch, is the posterior belly of the omo-hyoid. The *external* or *axillary border* (margo axillaris), so called from its relation to the hollow of the armpit (axilla), is much stouter than either of the others; it extends from the external angle above to the inferior angle below. The upper inch or so of this border, which lies immediately below the glenoid articular surface, is rough and tubercular (tuberositas infraglenoidalis), and affords attachment to the long head of the triceps. Below this it is usually crossed by a groove which marks the position of the dorsal artery of the scapula. The *superior angle* (angulus medialis) is sharp and more or less rectangular; the *inferior angle* (angulus inferior) is blunter and more acute; whilst the *external angle* (angulus lateralis) corresponds to that part of the bone which is sometimes called the **head**, and which supports the **glenoid surface** and the **coracoid process**.

The **glenoid surface** is a pyriform articular area, slightly concave from above downwards and from side to side; its border is but slightly raised above the general surface and affords attachment in the recent condition to the glenoid ligament, which helps to deepen the socket in which the head of the humerus rests. Below, the margin of the glenoid fossa is confluent with the **infraglenoid impression** (tuberositas infraglenoidalis), whilst above it blends with a tubercle (tuberositas supraglenoidalis), to which the long head of the biceps muscle is attached. Springing from the upper part of the head, in line with the superior border, is the **coracoid process** (processus coracoideus). The base of this is limited externally by the glenoid

edge, whilst internally it is separated from the superior border by the suprascapular notch. Rising upwards for a short space, it bends on itself at nearly a right angle, and ends in a process which is directed outwards and slightly forwards, overhanging the glenoid fossa above and in front. Compressed from above downwards, it has attached to its upper surface near its angle the conoid ligament, wide of which there is a rough area for the trapezoid ligament. Attached to its posterior border is the coraco-acromial ligament, whilst at its extremity and towards the front of its anterior border, is the combined origin of the biceps and coraco-brachialis, together with the insertion of the pectoralis minor. The **neck**

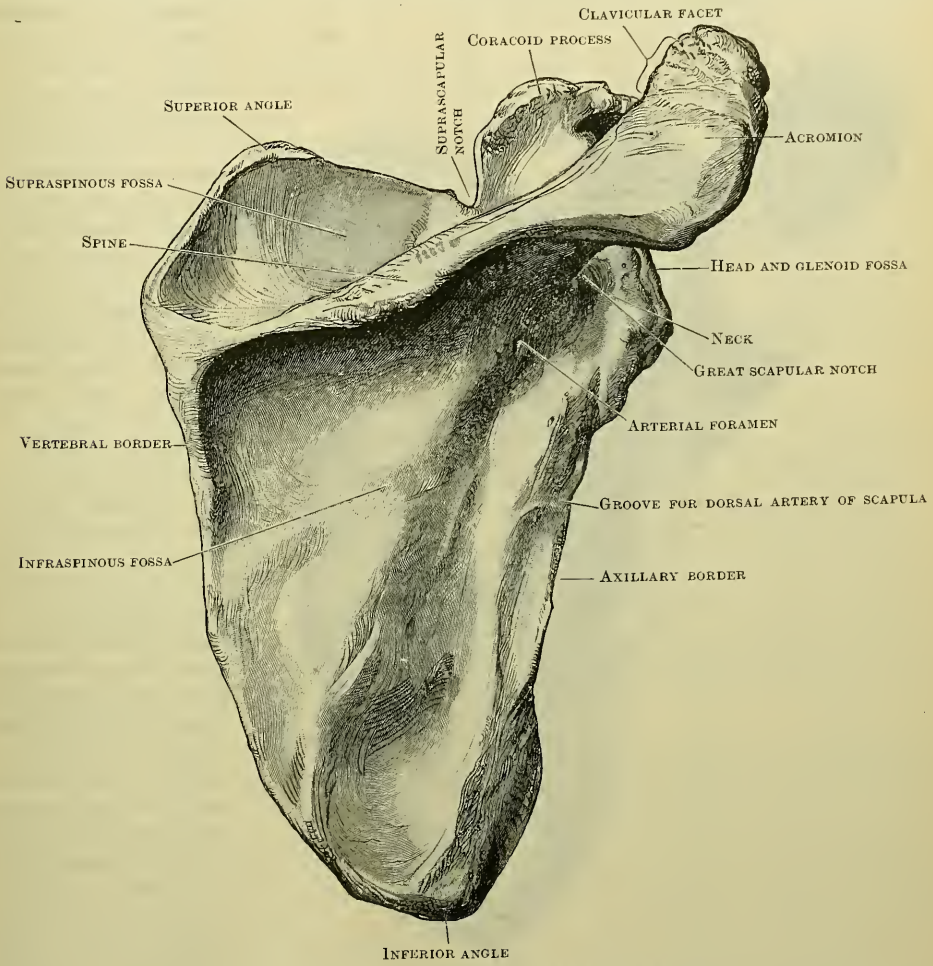


Fig. 131.—The Right Scapula as seen from Behind.

(collum scapulæ) is that somewhat constricted part of the bone which supports the head; it corresponds in front and behind to a line drawn from the suprascapular notch to the infraglenoid tubercle.

The body of the bone has two surfaces, a **dorsal** (facies dorsalis) and a **ventral** (facies costalis). The former is divided into two fossæ by an outstanding process of triangular form, called the **spine** (spina scapulæ). The attached border of this crosses the back of the body obliquely in a direction outwards and slightly upwards, extending from the vertebral border near the lower limit of its upper fourth towards the centre of the posterior glenoid edge, from which, however, it is separated by the **great scapular notch**, which here corresponds to the posterior aspect of the neck. The surfaces of the spine, which are directed upwards and downwards, are concave, the upper entering into the formation of the **supraspinous fossa**, which lies above it, the lower forming the upper wall of the **infraspinous fossa**,

which lies below it. The two fossæ are in communication with each other round the free external concave border of the spine, where that curves over the great scapular notch. The posterior free border of the spine is subcutaneous throughout its entire length. Its upper and lower edges are strongly lipped, and serve—the superior, for the attachment of the trapezius; the inferior, for the origin of the deltoid. The intervening surface varies in width—broad and triangular where it becomes confluent with the vertebral border, it displays a smooth surface, over which the tendinous fibres of the trapezius play; narrowing rapidly, it forms a surface of varying width which blends externally with a flattened process, the two forming a compressed plate of bone which arches across the scapular notch above and behind, and then curves forwards, upwards, and outwards to overhang the glenoid fossa. The internal border of this process is continuous with the upper margin of the spine, and is gently curved. The external border, more curved than the inner, with which it is united in front, is confluent with the inferior edge of the spine, with which it forms an abrupt bend, termed the **acromial angle**. The bone included between these two borders is called the **acromion process**. Of compressed form, it much resembles the acromial end of the clavicle, with which it articulates by means of a facet (facies articularis acromii) which is placed on its internal border near its anterior extremity. The superior surface of the acromion, which is broad and expanded, is subcutaneous, and is directed upwards and backwards, and in the normal position of the bone outwards as well. Its internal edge, where not in contact with the clavicle, has attached to it the fibres of the trapezius, whilst its external margin affords origin to the central part of the deltoid. At its anterior extremity it is connected with the coracoid process by means of the coraco-acromial ligament. Its under surface is smooth and overhangs the shoulder joint.

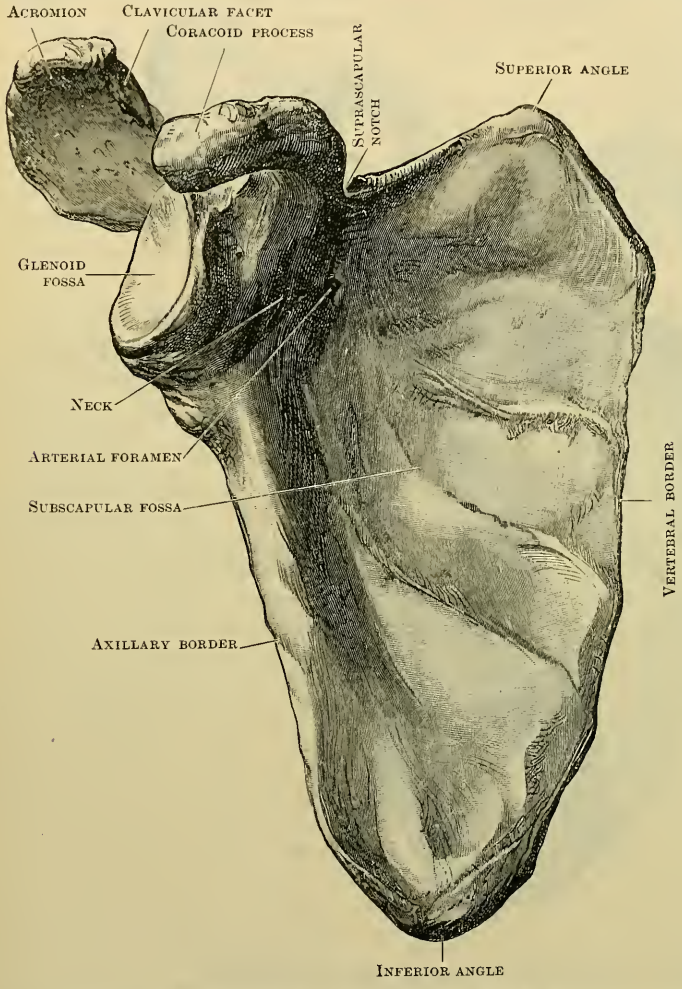


Fig. 132.—The Right Scapula as seen from the Front.

The **supraspinous fossa**, of much less extent than the infraspinous, is placed above the spine, the upper surface of which assists in forming its curved floor; in it is lodged the supraspinatus muscle. The suprascapular notch opens into it above, whilst below and externally it communicates with the infraspinous fossa by the great scapular notch, through which the suprascapular artery and nerve pass to reach the infraspinous fossa.

The **infraspinous fossa**, overhung by the spine above, is of triangular form. The axillary border of the bone limits it in front, whilst the vertebral margin bounds it behind; the greater part of this surface affords origin to the infraspinatus muscle, excepting a well-defined area which skirts the axillary border and inferior angle of the bone, and which affords an attachment to the fibres of origin, of the teres minor. This muscle extends along the posterior surface of the axillary border in its upper two-thirds, reaching nearly as high as the glenoid edge; whilst a crescentic surface, which occupies the lower third of the axillary border and curves backward round the posterior aspect of the inferior angle, furnishes an origin for the teres major muscle. Here also, near the inferior angle, are occasionally attached some of the fibres of the latissimus dorsi muscle.

The **ventral aspect** (facies costalis) of the body is hollow from above downwards and from side to side, the greatest depth being in correspondence with the spring of the spine from the dorsal surface. Its inner boundary, which is formed by the anterior lipped edge of the vertebral border, affords attachment to the fibres of insertion of the serratus magnus along the greater part of its extent. The area of insertion of this muscle is, however, considerably increased over the anterior aspects of the superior and inferior angles respectively. Running down from the head and neck above to the inferior angle below, there is a stout rounded ridge of bone, which imparts a fulness to the anterior aspect of the axillary border and increases the depth of the ventral hollow; to this, as well as to the floor of the fossa, the subscapularis muscle is attached. The tendinous intersections of this muscle leave their imprint on this surface of the bone in a series of three or four rough lines which converge towards the neck.

Nutrient Foramina.—Foramina for the passage of nutrient vessels are seen in different parts of the bone; the most constant in position is one which opens into the infraspinous fossa, about an inch or so from the scapular notch. Others are met with on the upper and under surfaces of the spine, on the ventral aspect near its deepest part, and also around the glenoid margin.

Connexions.—The scapula is not directly connected with the trunk, but articulates with the outer end of the clavicle, in union with which it forms the shoulder girdle supporting the humerus on its glenoid surface. Placed on the upper and back part of the thorax, it covers the ribs from the second to the seventh inclusive. Possessed of a wide range of movement, it alters its position according to the attitude of the limb, rising or falling, being drawn inwards or outwards, or being rotated upon itself according as the arm is moved in various directions. These changes in position can easily be determined by recognising the altered relations of the subcutaneous and bony prominences, more especially the former, which include the spine, the acromion process, and the lower half of the vertebral border.

Architecture.—For so light and thin a bone, the scapula possesses a remarkable rigidity. This is owing to the arrangement of its parts. Stout and thick where it supports the glenoid surface and coracoid process, the rest of the bone is thin, except along the axillary border; but strength is imparted to the body by the manner in which the spine is fused at right angles to its posterior surface.

Variations.—The most common variation met with is a separated acromion process. In these cases there has been failure in the ossific union between the spine and acromion, the junction between the two being effected by a layer of cartilage or an articulation possessing a joint cavity. The condition is usually symmetrical on both sides, though instances are recorded where this arrangement is unilateral. Very much rarer is the condition in which the coracoid process is separable from the rest of the bone. The size and form of the suprascapular notch differs. In certain cases the superior border of the bone describes a uniform curve reaching the base of the coracoid without any indication of a notch. In some scapulæ, more particularly in those of very old people, the floor of the subscapular fossa is deficient owing to the absorption of the thin bone, the periosteal layers alone filling up the gap. Congenital elevation of the scapula is due to defective development of the muscles connected with it.

At birth the vertical length of the bone is less in proportion to its width than in the adult.

Ossification.—Ossification begins in the body of the cartilaginous scapula about the end of the second month of fœtal life. At birth the head, neck, body, spine, and base of the coracoid process are well defined; the vertebral border, inferior angle, glenoid fossa, acromion and coracoid processes, are still cartilaginous. The centre for the upper and fore part of the coracoid appears in the first year, and fusion along an oblique line leading from the upper edge of the glenoid fossa to the conoid tubercle is complete about the fifteenth year. A separate centre (subcoracoid), which ultimately includes the upper part of the glenoid fossa and external part of the coracoid process, makes its appearance about the tenth year, and fuses with the surrounding bone about sixteen or seventeen. Up till the age of puberty the acromion remains cartilaginous; centres, two or more in number,

then make their appearance, which coalesce and ultimately unite with the spine about the twenty-fifth year. Failure of union may, however, persist throughout life (see *ante*, Variations).

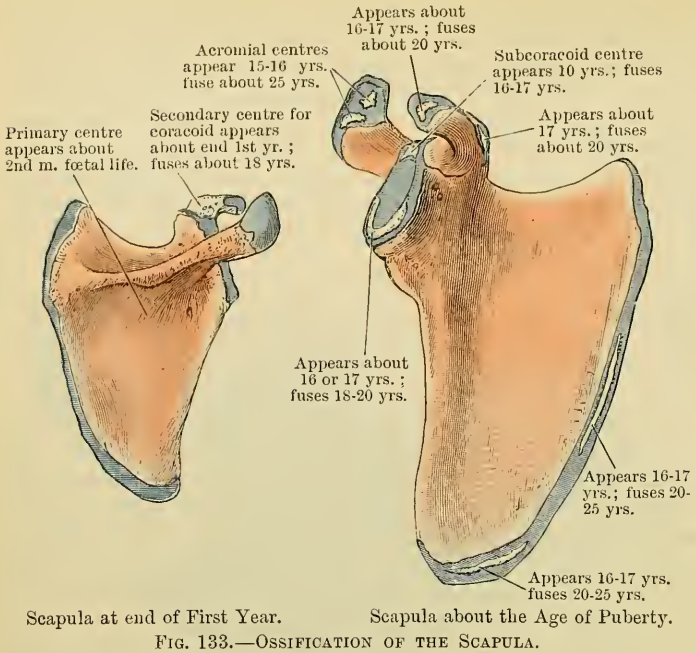


FIG. 133.—OSSIFICATION OF THE SCAPULA.

Ossification commences in the cartilage in the inferior angle about puberty, and independently and a little later, along the vertebral margin, fusion with the body occurring at from twenty to twenty-five years.

Small scale-like epiphyses make their appearance on the upper surface and at the extremity of the coracoid, and are completed about the twentieth year. A thin epiphysial plate develops over the lower part of the glenoid fossa about sixteen or seventeen, fusion being complete about eighteen or twenty years of age.

THE HUMERUS.

The **humerus**, or bone of the upper arm, articulates with the scapula above and with the bones of the forearm, the radius and ulna, below. Its upper end comprises the **head** and **great** and **small tuberosities**; its **shaft**, which is longer than any of the other bones of the upper extremity, is cylindrical above and flattened below, At the inferior extremity, which is expanded to form the **condyles** on either side, it supports the **trochlear** and **capitellar** articular surfaces for the ulna and radius respectively.

The **superior extremity** is the thickest and stoutest part of the bone. The **head** (caput humeri), which forms about one-third of a spheroid and is covered by articular cartilage, is directed upwards, inwards, and slightly backwards, and rests in the glenoid fossa of the scapula; the convexity of its surface is most pronounced in its posterior half. Separating the head from the tuberosities externally is a shallow groove, which fades away on the surface of the bone which supports the articular part inferiorly. This is named the **anatomical neck** (collum anatomicum) and serves for the attachment of the capsule of the shoulder joint. The articular edge of the groove opposite the small tuberosity is usually notched for the attachment of the superior gleno-humeral ligament. The **great tuberosity** (tuberculum majus) abuts on the outer side of the head and becomes continuous with the shaft below. Its upper surface forms a quadrant, which is subdivided into three more or less smooth areas of unequal size. Of these the highest and anterior is for the insertion of the supraspinatus muscle, the middle for the infraspinatus, whilst the lowest and posterior serves for the insertion of the teres minor muscle. The outer surface of this tuberosity, which bulges beyond the line of the shaft, is rough and pierced by numerous foramina. Anteriorly the great tuberosity is separated from the **small tuberosity** (tuberculum minus) by a well-defined furrow, called the **bicipital groove** (sulcus intertubercularis), from the circumstance that the tendon of origin of the long head of the biceps muscle is lodged within it. The **small tuberosity** lies in front of the outer half of the head; it forms a pronounced elevation, which fades into the shaft below. The surface of this tuberosity is faceted above and in front for the insertion of the sub-scapularis muscle, whilst externally it forms the

prominent inner lip of the bicipital groove. Below the head and tuberosities the shaft of the bone rapidly contracts, and is here named the **surgical neck** (collum chirurgicum) owing to its liability to fracture at this spot.

The **shaft**, or body (corpus humeri), is cylindrical in its upper half. On it the **bicipital groove** may be traced downwards and slightly inwards, along its anterior surface. The edges of the groove, which are termed its lips, are confluent above with the great and small tuberosities respectively. Here they are prominent, and form the crests of the great and small tuberosities (cristæ tuberculi majoris et minoris). Inferiorly the lips of the bicipital groove gradually fade away, the inner more rapidly than the outer, which latter may usually be traced down to a rough elevation placed on the outer side of the shaft about its middle called the **deltoid eminence**. Into the outer lip of the bicipital groove are inserted the fibres of the pectoralis major muscle; hence it is sometimes described as the pectoral ridge. To the floor of the groove the latissimus dorsi is attached; whilst the teres major muscle is inserted into the inner lip.

The **deltoid eminence** (tuberositas deltoidea), to which the powerful deltoid muscle is attached, is a rough, slightly elevated V-shaped surface, placed on the outer side of the shaft about its middle. The anterior limb of the V is parallel to the axis of the shaft, and is continuous with the outer lip of the bicipital groove above, whilst the posterior limb of the V winds obliquely round the outer side of the bone towards the posterior surface, where it becomes continuous with a slightly elevated and occasionally rough ridge which leads up the back of the bone towards the great tuberosity superiorly; from this latter ridge the outer head of the triceps muscle arises.

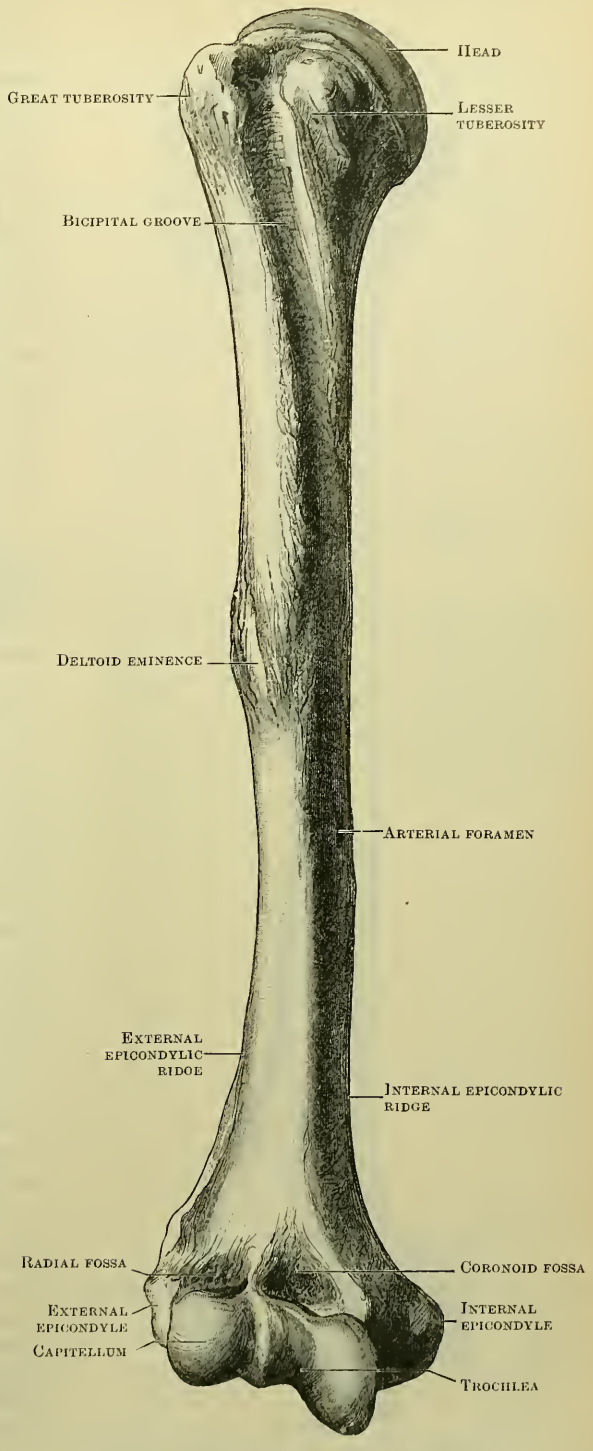


Fig. 134.—Anterior View of the Right Humerus.

The inner surface of the shaft about its middle inclines to form a rounded

border, on which there is often a rough linear impression marking the insertion of the coraco-brachialis muscle. Below this the shaft becomes compressed and expanded laterally, ending inferiorly on either side in the **condyles.** Its surfaces are now anterior and posterior, being separated from each other by two clearly defined borders, the **epicondylic ridges.** Of these, the internal, **margo medialis**, is the more curved and less prominent, and is continuous above with the surface to which the coraco-brachialis is attached, whilst inferiorly it ends by blending with the internal condyle. The external epicondylic ridge, **margo lateralis**, is straighter and more projecting; its edge is usually distinctly lipped. Confluent with the external condyle inferiorly, it may be traced upwards to near the deltoid eminence, where it turns backwards more or less parallel to the posterior oblique border of that impression, to be lost on the posterior surface of the shaft. The interval between this border and the deltoid eminence is thus converted into a shallow oblique furrow, which winds round the outer surface of the bone just below its middle; this constitutes the **musculo-spiral groove** (sulcus radialis) along which the musculo-spiral nerve, together with the superior profunda artery, passes from the back to reach the front of the arm. To the epicondylic ridges are attached the intermuscular septa, whilst the external in its upper two-thirds furnishes a surface for the origin of the brachio-radialis (supinator-longus), and in its lower third for the extensor carpi radialis longior muscle.

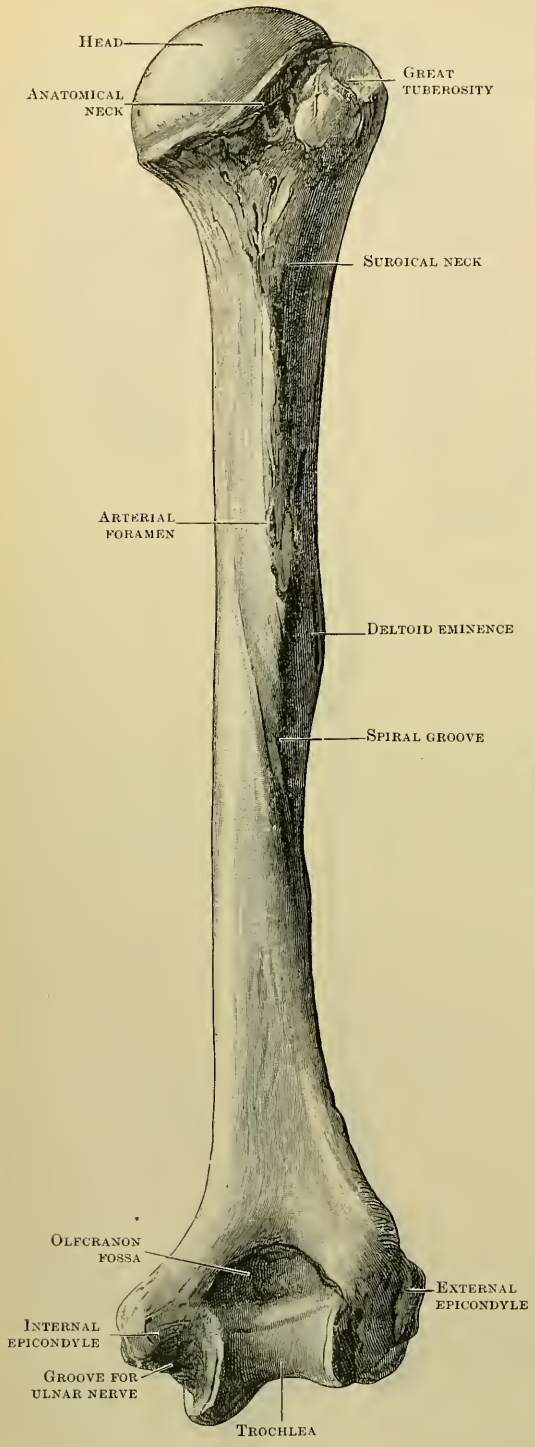


Fig. 135.—Posterior View of the Right Humerus.

The anterior surface of the lower half of the shaft is of elongated triangular form, the base corresponding to the inferior extremity of the bone. Running down the centre of this is a broad, rounded, elevated ridge, most pronounced above, where it joins the deltoid eminence, and sloping on either side towards the epicondylic ridges; it is into the outer of these slopes that the musculo-spiral groove flows. Inferiorly the elevated surface spreads out, and becomes confluent with the condyles, more correctly termed the epicondyles. The **internal epicondyle** (epicondylus medialis) is the more prominent of the two, and furnishes a surface for the origin of the pronator radii teres, and

the superficial flexor muscles of the forearm. The **external epicondyle** (epicondylus lateralis), stunted and but little projecting, serves for the attachment of the common tendon of origin of the extensor muscles. The brachialis anticus muscle has an extensive origin from the anterior surface of the lower half of the shaft, including between its upper slips the insertion of the deltoid.

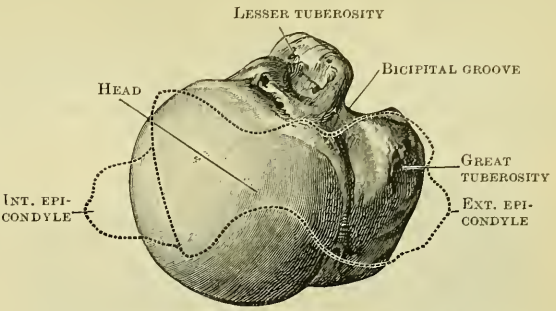


FIG. 136.—THE HEAD OF THE RIGHT HUMERUS AS SEEN FROM ABOVE (with the outline of the lower extremity in relation thereto shown in dotted line).

The posterior surface of the lower half of the shaft is smooth and rounded from side to side; somewhat flattened below, where the whole shaft tends to incline forwards, it becomes continuous on either side with the posterior surfaces of the epicondyles, the inner of which is grooved for the passage of the ulnar nerve, whilst the external supplies an origin for the anconeus muscle. The inner head of the triceps muscle has an extensive origin from the posterior surface of the lower two-thirds of the shaft, internal to and below the musculo-spiral groove.

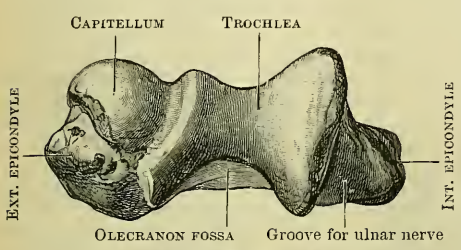


FIG. 137.—THE LOWER EXTREMITY OF THE RIGHT HUMERUS AS SEEN FROM BELOW.

The **lower extremity** of the humerus is furnished with two articular surfaces (the condyles proper), the outer of which, called the **capitellum** (capitulum), for articulation with the upper surface of the head of the radius, is a rounded eminence, placed on the anterior surface and lower border, but not extending upwards on the posterior surface of the inferior end of the bone. Above it, in front, there is a shallow depression (fossa radialis), into which the margin of the head of the radius sinks when the elbow is strongly flexed. A shallow groove separates the capitellum internally from the **trochlea**, which is a grooved articular surface, with prominent edges winding spirally round the lower extremity of the shaft. The spiral curves from behind forwards and inwards, and its axis is slightly oblique to the long axis of the shaft. The inner lip is the more salient of the two, and forms a sharp and well-defined margin to the articular area; its cartilage-covered surface is slightly convex. The outer lip, much less prominent, is rounded off into the articular groove which separates it from the capitellum, posterior to which, however, it is carried up as a more or less definite crest. It is by means of the trochlea that the humerus articulates with the great sigmoid cavity of the ulna. On the anterior surface of the bone, immediately above the trochlea, is a depression—the **coronoid fossa** (fossa coronoidea), into which the coronoid process of the ulna slips in flexion of the joint, whilst in a corresponding position on the back of the lower end of the shaft there is a hollow, called the **olecranon fossa** (fossa olecrani), just above the trochlea posteriorly. Into this the olecranon process sinks when the elbow is extended. The two fossæ are separated

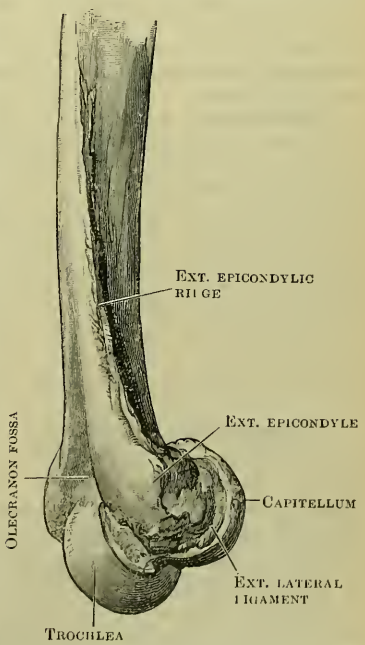


FIG. 138.—THE LOWER END OF THE RIGHT HUMERUS AS SEEN FROM THE OUTER SIDE.

by a thin translucent layer of bone which may be deficient, thus leading to the formation of a foramen between the two hollows in the macerated bone. The anterior part of the capsule of the elbow-joint is attached to the superior margins of the radial and coronoid fossæ in front, whilst the posterior ligament is connected with the upper border and lateral edges of the olecranon fossa behind. The strong internal and external lateral ligaments are attached superiorly to the internal and external epicondyles respectively. The proportionate length of the humerus to the body height is as 1 is to 4·93–5·25.

Nutrient foramina are usually to be seen, one at or near the surface for the insertion of the coraco-brachialis, the other usually close to the hinder border of the deltoid eminence; both have a downward direction. Numerous vascular foramina are scattered along the line of the anatomical neck, the larger ones being situated near the upper end of the bicipital groove.

Connexions.—The humerus articulates with the scapula above, and radius and ulna below. Embedded as the humerus is in the substance of the upper arm, its shaft and head are surrounded on all sides. It is only at its lower part that it comes into direct relation with the surface, the internal epicondyle forming a characteristic projection on the inner side of the elbow; whilst the external epicondyle, less prominent, and the external epicondylic ridge can best be recognised when the elbow is bent.

Architecture.—The shaft consists of a layer of compact bone surrounding a long medullary canal. The outer shell, thickest in the lower third of the bone, gradually thins until it reaches the superior epiphysial line, where it forms a layer no thicker than stout paper. Inferiorly the external shell is thicker and stouter than above, until it reaches the epicondyles, below which the articular surfaces are formed of a layer of compact spongy bone. The upper end of the medullary canal is surrounded by loose spongy tissue, the fibres of which arch inwards from the inner surface of the compact outer layer, whilst inferiorly the cancellous tissue which springs from the outer shell sweeps downwards in a radiating fashion on either side of the olecranon fossa towards the epicondyles. Above the olecranon fossa there are a number of laminæ of dense bone which arch across from one side to the other, the convexity of the arches being directed downwards. The superior epiphysis, formed of spongy bone, is united to the shaft by a wavy line, concave externally and convex internally, leading from the base of the great tuberosity on the outer side to the inferior articular edge on the inner side. The mass above this includes the head and two tuberosities. The spongy tissue of the head is fine, and is arranged generally in lines radial to its surface; that of the great tuberosity is more open, and often displays large spaces towards its interior, which in old bones communicate freely with the medullary cavity of the shaft. The general direction of the fibres is parallel to the outer surface of the tuberosity. The lower articular end is formed of fine spongy tissue, more compact towards the surface, and arranged in lines more or less at right angles to its articular planes. In the adult the principal nutrient canal, viz. that which opens on the surface near the insertion of the coraco-brachialis, traverses the outer compact wall of the shaft obliquely downwards for a distance of two and a quarter inches before it opens into the medullary cavity.

Variations.—As has been already stated, the olecranon and coronoid fossæ may communicate with each other in the macerated bone. The resulting supratrochlear foramen is most commonly met with in the lower races of man, as well as in the anthropoid apes, and in some other mammals. The occurrence of a hook-like spine, called the epicondylic process, which projects in front of the internal epicondylic ridge, is not uncommon. Its extremity is connected with the internal epicondyle by means of a fibrous band, underneath which the median nerve, accompanied by the brachial artery, or one of its large branches, may pass, or in some instances, the nerve alone, or the artery unaccompanied by the nerve. This process is the homologue in a rudimentary form of a canal present in many animals, notably in the carnivora and marsupials. In addition to the broad musculo-spiral groove already described, and which is no doubt produced by the twisting or torsion of the shaft, there is occasionally a distinct narrow groove posterior to it, which marks precisely the course of the musculo-spiral nerve as it turns round the outer side of the shaft of the bone.

Ossification.—At birth the shaft of the humerus is usually the only part of the bone ossified, if we except the occasional presence (22 per cent) of an ossific centre in the head. (H. R. Spencer, *Journ. Anat. and Physiol.* vol. xxv. p. 552.) The centre for the **shaft** makes its appearance early in the second month of intrauterine life. Within the first six months after birth a centre usually appears for the **head**; this is succeeded by one for the **great tuberosity** during the second or third year. These soon coalesce; and a third centre for the **small tuberosity** begins to appear about the end of the third year, or may be delayed till the fourth or fifth year. These three centres are all blended by the seventh year, and form an **epiphysis**, which ultimately unites with the shaft about the age of twenty-five. It may be noticed that the superior end of the diaphysis is conical and pointed in the centre, over which the epiphysis fits as a cap, an arrangement which thus tends to prevent its displacement before union has occurred. The first centre to appear in the *lower extremity* is that for the **capitellum** about the second or third

year. This extends inwards, and forms the outer half of the **trochlear surface**, the centre for the inner half not making its appearance till the eleventh or twelfth year. Separate centres are developed in connexion with the **epicondyles**; that for the external appears about the twelfth year, and rapidly coalescing with the centres for the capitellum and trochlea forms an **epiphysis**, which unites with the shaft about the sixteenth or seventeenth year. The centre for the **internal epicondyle** appears about the fifth year; it forms a separate **epiphysis**, which unites with the shaft about eighteen or nineteen. These two epiphyses at the lower end of the bone are separated by a down-growth of the

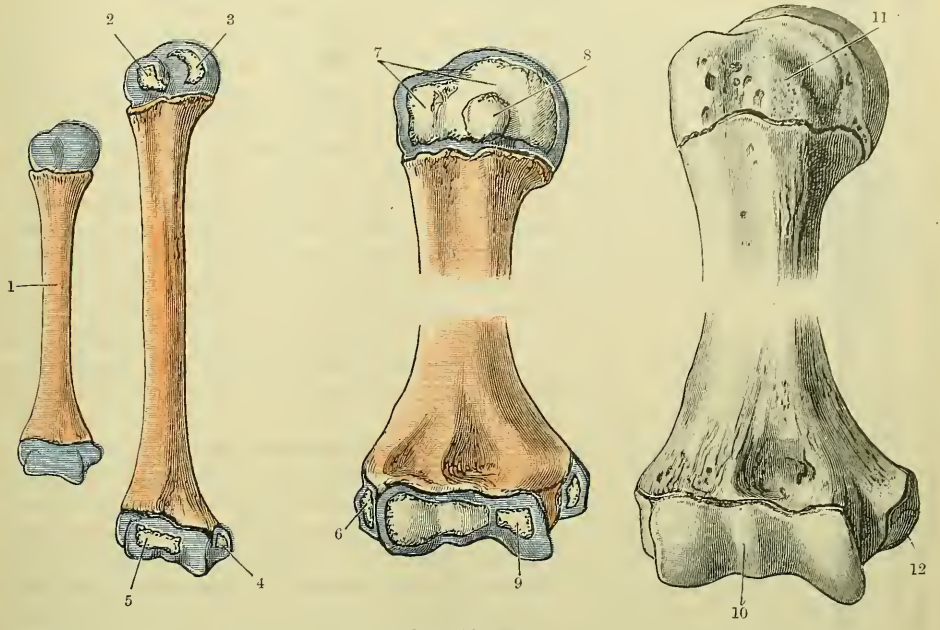


FIG. 139.—OSSIFICATION OF THE HUMERUS.

1. Appears early in 2nd month fœtal life.
2. For tuberosity, appears 2 to 3 years.
3. For head, appears within first 6 months.
4. For internal condyle, appears about 5 years.
5. For capitellum, appears 2 to 3 years.
6. Appears about 12 years.
7. Centres for head and great tuberosity, coalesce about 5 years.
8. Centre for small tuberosity fuses with other centres about 7 years.
9. Appears about 11 or 12 years.
10. Inferior epiphysis fuses with shaft about 16 to 17 years.
11. Superior epiphysis fuses with shaft about 25 years.
12. Fuses with shaft about 17 to 18 years.

shaft, which lies between the internal epicondyle and the trochlea, and forms part of the base and inner side of the latter process.

The epicondylic process when present is developed from the diaphysis, and has been observed to be already well ossified by the third year. ("Proc. Anat Soc." *Journ. Anat. and Physiol.* 1898.)

THE ULNA.

Of the two bones of the forearm, the **ulna**, which is placed internally, is the longer. It consists of a large superior extremity supporting the **olecranon** and **coronoid** processes; a shaft tapering from above downwards; and a small rounded inferior end called the **head**.

Superior Extremity.—The **olecranon process** (olecranon) lies in line with the shaft. Its posterior surface, more or less triangular in form, is smooth and subcutaneous and covered by a bursa. Its superior aspect, which forms with the posterior surface a nearly rectangular projection—the tip of the elbow—furnishes a surface for the insertion of the tendon of the triceps muscle, together with a smooth area which is overlain by the same tendon, but separated from it by a bursal sac. To the anterior crescentic border of this process are attached the fibres of the posterior part of the capsule and portion of the internal lateral ligament of the elbow-joint. The anterior surface is articular, and enters into the formation of the **great sigmoid cavity**.

The **coronoid process** (processus coronoideus) is a bracket-like process, which juts forwards from the fore and upper part of the shaft, and is fused with the olecranon process superiorly. By its upper surface it enters into the formation of the great sigmoid cavity, whilst its anterior aspect, which is separated from its upper side by a sharp irregular margin, slopes downwards and backwards to become confluent with the anterior surface of the shaft. Of triangular shape, this area, which is rough and tubercular, terminates inferiorly in an oval elevated tubercle (tuberositas ulnæ), into which the tendon of the brachialis anticus muscle is inserted. Of the lateral margins of the coronoid process, the inner is usually the better defined. Above, where it joins the superior border, there is generally a salient tubercle, to which one of the heads of origin of the flexor sublimis digitorum muscle is attached, whilst below this point the inner border furnishes origins for the pronator radii teres, and occasionally for the flexor longus pollicis muscles, from above downwards. The smooth inner surface of the coronoid process merges with the olecranon behind, and with the internal surface of the shaft below.

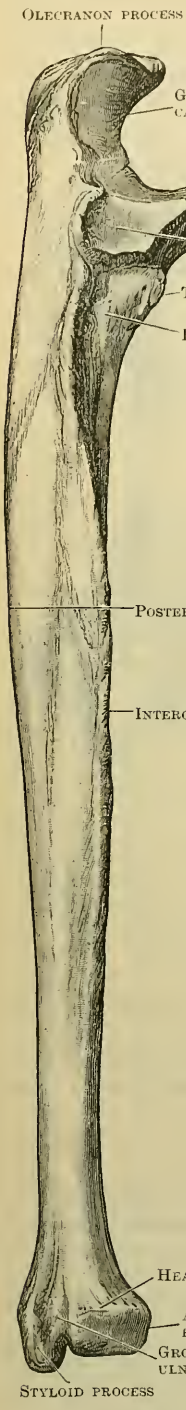


Fig. 140.—The Right Ulna as viewed from the Outer Side.

The **great sigmoid cavity** (incisura semilunaris), for articulation with the trochlea of the humerus, is a semicircular notch, the upper part of which is formed by the anterior surface of the olecranon, whilst below it is completed by the upper surface of the coronoid process. Constricted towards its deepest part by the notching of its lateral borders, the articular surface is occasionally crossed by a narrow impression which serves to define the olecranon process above from the coronoid below. The articular area is divided into an inner portion, slightly concave transversely, and an outer part, transversely convex to a slight degree, by a longitudinal smooth ridge which extends from the most prominent part of the border of the olecranon above to the most outstanding point of the coronoid process below. The margins of the great sigmoid cavity are sharp and well defined, and serve, with the exception of the area occupied by the small sigmoid cavity, for the attachment of the capsule of the elbow-joint.

The **small sigmoid cavity**, placed on the outer side of the coronoid process, is an oblong articular surface for the reception of the head of the radius. It encroaches on the lower and outer part of the great sigmoid notch, so as to narrow it considerably. Separated from it by a rectangular curved edge, it displays a surface which is plane from above downwards, and concave from before backwards. Its anterior extremity is narrower and more pointed than its posterior, and becomes confluent with the anterior edge of the coronoid process, at which point the orbicular ligament, which retains the head of the radius in position, is attached in front. Its posterior border, wider and more outstanding, lies in line, and is continuous with the interosseous margin

of the shaft. Behind this border, the orbicular ligament is attached posteriorly.

The **shaft** of the ulna (corpus ulnæ), which is nearly straight, or but slightly curved, is stout and thick above, gradually tapering towards its lower extremity. It may be divided into two surfaces, a flexor and an extensor, by two well-defined borders, an **external** or **interosseous** (crista interossea), and a **posterior** (margo dorsalis), which latter is subcutaneous throughout its whole length.

The outer, or **interosseous border** (crista interossea), is crisp and sharp in the upper three-fourths of the shaft, but becomes faint and ill-defined in the lower fourth. To this, with the exception only of the part which forms the posterior boundary of the bicipital hollow, is attached the interosseous membrane which connects the two bones of the forearm. The **posterior border** (margo dorsalis), of sinuous outline, curving outwards above, and slightly inwards below, is continuous superiorly with the triangular subcutaneous area on the back of the olecranon, being formed by the confluence of the borders which bound that surface; well marked above, it becomes faint and more rounded below, but may be traced downwards to the posterior surface of the base of the styloid process. To this border is attached an aponeurosis common to the flexor carpi ulnaris, extensor carpi ulnaris, and flexor profundus digitorum muscles. A noteworthy feature in connexion with this part of the shaft is the fact that it is subcutaneous, and can easily be felt beneath the skin throughout its whole length.

The **flexor surface** corresponds to the front and inner side of the shaft. It is frequently described as consisting of two surfaces, an anterior and an internal, which are separated by a rounded anterior border (margo volaris), which extends from the tubercle above towards the styloid process below. The prominence of this ridge varies in different bones, being well marked in bones of a pronounced type, but corresponding merely to the rounding of the surfaces in poorly developed specimens. The flexor aspect of the bone affords an extensive origin to the flexor profundus digitorum muscle, which clothes its anterior and inner sides in its upper three-fourths, reaching as far back as the posterior border, and extending upwards as high as the inner side of the coronoid process. Immediately below the small sigmoid cavity there is a hollow triangular area, limited behind by the upper part of the interosseous crest, and defined in front by an oblique line which extends downwards and backwards from the outer margin of the coronoid process. In this hollow the bicipital tubercle of the radius rests when the forearm is in the prone position, and to its floor are attached the fibres of origin of the supinator radii brevis muscle. The lower fourth of the shaft is crossed by the fibres of the pronator quadratus muscle, which derives its origin from a more or less well-defined crest, which winds spirally downwards and backwards towards the front of the root of the styloid process, and is continuous above with the so-called anterior border.

The **extensor aspect** of the shaft lies posteriorly between the posterior border and the interosseous crest. At its upper part it is placed behind the great and small sigmoid cavities, extending on to the outer side of the olecranon. Here an area corresponding to the upper third of the length of the bone is marked off inferiorly by an oblique ridge which leaves the interosseous crest about an inch or more below the hinder edge of the small sigmoid cavity. Into this somewhat triangular surface the fibres of the anconeus are inserted. Below this the posterior surface is subdivided by a faint longitudinal ridge, the bone between which and the interosseous crest furnishes origins for the extensor ossis metacarpi pollicis, extensor longus pollicis, and extensor indicis muscles, in order from above downwards. The surface of bone between the posterior border and the afore-mentioned longitudinal line is smooth and overlain by the extensor carpi ulnaris muscle.

The **inferior extremity** of the ulna presents a rounded head (capitulum ulnæ), from which, on its inner and posterior aspect, there projects downwards a cylindrical pointed process called the **styloid process** (processus styloideus). To the extremity of this latter is attached the internal lateral ligament, whilst in front it has connected with it the antero-internal portion of the capsule of the wrist-joint. The antero-external half of the circumference of the head is furnished with a smooth narrow convex articular surface, which fits into the sigmoid cavity of the radius.

Its inferior surface, flat and semilunar in shape, and separated from the root of the styloid process by a well-marked groove, rests on the upper surface of the triangular fibro-cartilage of the wrist, the apex of which is attached to the groove just mentioned. The margins of the head in front and behind the radial articular surface have attached to them the anterior and posterior inferior radio-ulnar ligaments. The hinder and outer surface of the styloid process is channelled by a groove which separates it from the posterior surface of the head, and extends some little way up the posterior aspect of the lower end of the shaft. In this is lodged the tendon of the extensor carpi ulnaris muscle. The proportionate length of the ulna to the body height is as 1 is to 6·26–6·66.

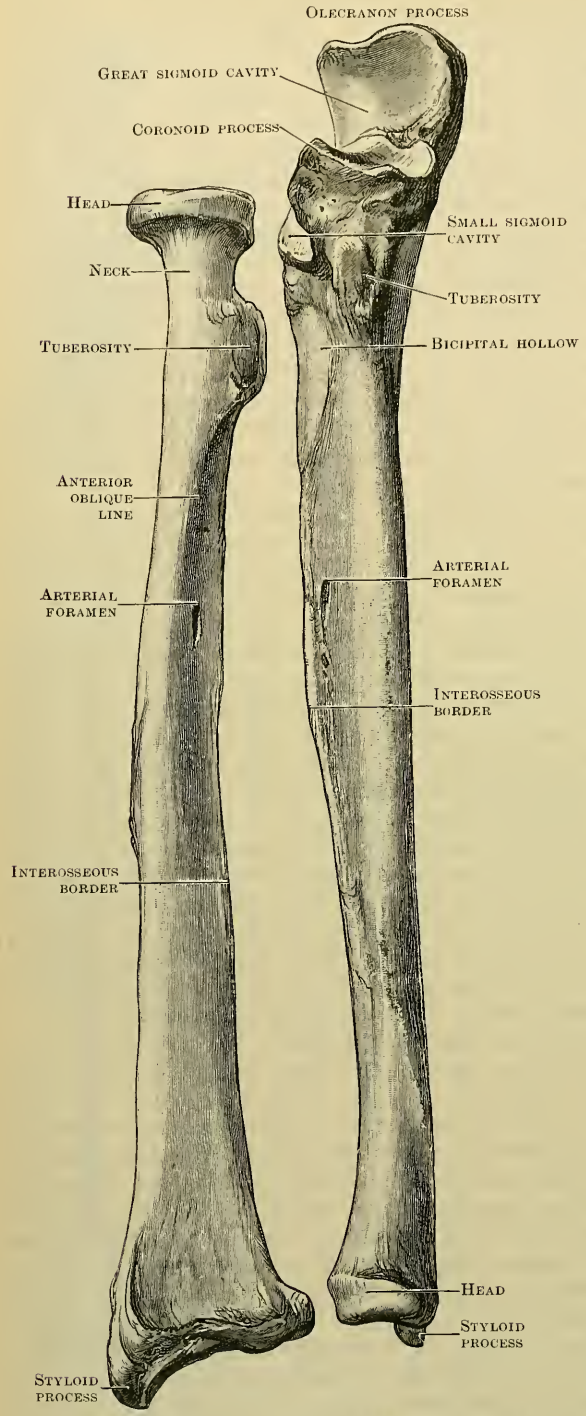


Fig. 141.—The Radius and Ulna as seen from the Front.

Nutrient Foramina.—A foramen, having an upward direction for the nutrient artery of the shaft, opens on the anterior surface of the bone from two to three inches below the tuberosity. Vascular canals of large size are seen above and behind the small sigmoid cavity, just posterior to the notched external border of the great sigmoid cavity. At the lower end of the bone similar openings are seen in the groove between the styloid process and the inferior articular surface of the head.

Connexions.—The ulna articulates above with the trochlea of the humerus. On the outer side it is in contact with the radius above and below, the superior radio-ulnar articulation being formed by the head of the radius and the small sigmoid cavity of the ulna, the inferior radio-ulnar joint comprising the head of the ulna, which fits into the sigmoid cavity of the radius. Between these two joints the shafts of the bones are united by the interosseous membrane. The inferior surface of the head of the ulna does not articulate with the carpus, but rests on the upper surface of the interposed triangular fibro-cartilage. The ulna is superficial throughout its entire extent. Superiorly the olecranon process can be readily recognised, particularly when the elbow is bent, as in this position the olecranon is withdrawn from the olecranon fossa of the humerus in which it rests when the joint is extended. Below this the subcutaneous triangular area on the back of the olecranon can be easily determined, and from it the posterior border of the bone can readily be traced along the line of the "ulnar furrow" to the styloid process below. With the hand supine this latter process can be felt to the inner side and slightly behind the wrist. When the hand is pronated, the lower end of the radius rolls round the lower extremity of the ulna, and the antero-external surface of the head of

the latter bone now forms a well-marked projection on the back of the wrist in line with the cleft between the little and ring fingers.

Architecture.—The weakest parts of the bone are the constricted portion of the great sigmoid cavity, and the shaft in its lower third, the bone being most liable to fracture at these points. On section the medullary cavity is seen to extend upwards as high as the base of the coronoid process; inferiorly it reaches as low as the upper end of the lower fifth of the bone. The walls of the shaft, which are formed of dense bone, are much thicker posteriorly than anteriorly. Above they are continuous with the front of the coronoid process and the back of the olecranon, where they are composed of layers of looser texture, which, however, gradually become thinner as the points of these processes are reached. Inferiorly they gradually taper until the head and styloid process are reached, round which they form a thin shell, considerably thickened, however, in the region of the groove for the extensor carpi ulnaris muscle. The bulk of the upper extremity is formed of loose cellular bone, arranged in a series of arcades, stretching from the anterior to the posterior wall over the upper end of the medullary canal. Above the constricted part of the great sigmoid cavity the bone displays a different structure; here it is formed of spongy bone, of closer texture, arranged generally in lines radial to the articular surface. At the point of constriction of the great sigmoid cavity the layer immediately subjacent is much denser and more compact.

The lower fifth of the bone is formed of loose spongy bone, the fibres of which have a general longitudinal arrangement; towards its extremity the meshes become smaller.

Variations.—Cases of partial or complete absence of the ulna through congenital defect have been recorded. Rosenmüller has described a case in which the olecranon was separated from the upper end of the bone, resembling thus in some respects the patella. In powerfully developed bones there is a tendency to the formation of a sharp projecting crest corresponding to the insertion of the triceps.

Ossification.—The ulna is ossified from one primary and two or more secondary centres. The centre for the shaft appears early in the second month of fœtal life. At birth the shaft and a considerable part of the upper extremity, including the coronoid process, are ossified, as well as part of the lower extremity. The olecranon process and the inferior surface of the head and the styloid process are cartilaginous. About ten years of age a secondary centre appears in the cartilage at the upper end of the bone, and forms an epiphysis which unites with the shaft about sixteen. A scale-like centre appears in the cartilage of the head about the sixth year, from which the under surface of that part of the bone is developed, and by the extension of which the styloid process is also ossified; this epiphysis does not unite with the shaft till the twentieth or twenty-third year. Independent centres for the styloid process and for the extreme edge of the olecranon have also been described. The student may here be warned that the epiphysial line between the shaft and superior or olecranon epiphysis does not correspond to the constricted part of the great sigmoid cavity, but lies considerably above it.

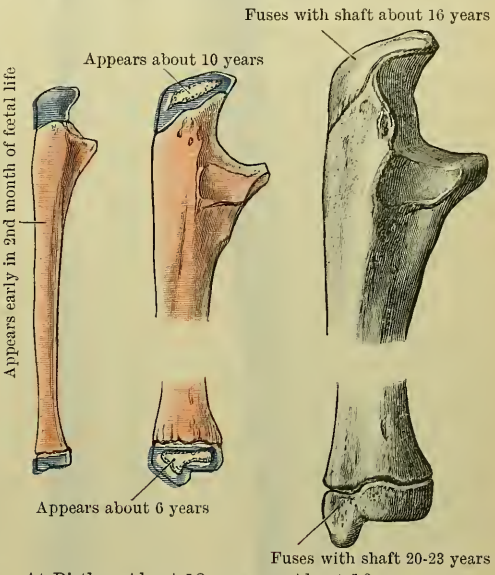


Fig. 142.—The Ossification of the Ulna.

The Radius.

The **radius**, or outer bone of the forearm, is shorter than the ulna, with which it is united on the inner side. Superiorly it articulates with the humerus, and below supports the carpus. It consists of a **head**, a **neck**, a **tubercle**, a **shaft**, and an expanded **lower extremity**. The shaft is narrow above, but increases in all its diameters below.

Upper Extremity.—The **head** (capitulum) is disc-shaped and provided with a shallow concave surface (fovea capituli radii) superiorly for articulation with the capitellum of the humerus. The circumference of the head (circumferentia articularis) is smooth and is embraced by the orbicular ligament. On the inner side it is usually much broader, and displays an articular surface, plane from above down-

wards, which rolls within the small sigmoid cavity of the ulna in the movements of pronation and supination. The character of the outer half of the circumference differs from the inner in being narrower, and rounded from above downwards.

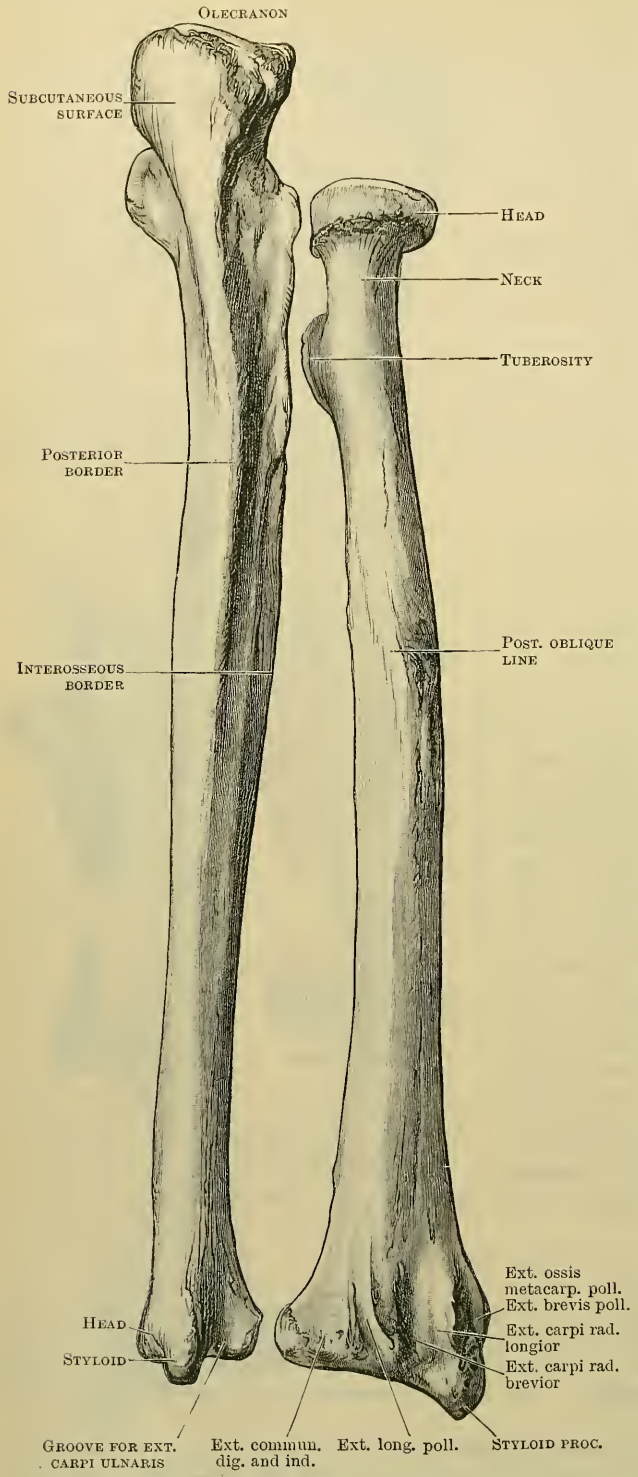


Fig. 143.—The Radius and Ulna as seen from Behind.

The **neck** (collum radii) is the constricted part of the shaft which supports the head, the overhang of the latter being greatest towards the outer and posterior side. Below the neck, on the inner side, there is an outstanding oval prominence, the **bicipital tuberosity** (tuberositas radii). The posterior part of this is rough for the insertion of the biceps tendon, whilst the anterior half is smooth and covered by a bursa which intervenes between it and the tendon.

The **shaft** (corpus radii), which has an outward curve and is narrow above and broad below, is wedge-shaped on section. The edge of the wedge forms the sharp inner interosseous margin of the bone (crista interossea), whilst its base corresponds to the thick and rounded outer border over which the anterior or flexor surface becomes confluent with the posterior or extensor surface.

The **internal or interosseous border**, faint above where it lies in line with the posterior border of the bicipital tubercle, becomes sharp and prominent in the middle third of the bone. Below this it splits into two faint lines, which lead to either side of the sigmoid cavity on the lower end of the bone, thus including between them a narrow triangular area into which the deeper fibres of the pronator radii quadratus muscle are inserted. To this border, as well as to the posterior of the two divergent lines, the interosseous membrane is attached.

The **external border** (oftentimes described as the external surface) is thick and rounded above, but becomes thinner and more prominent below, where it merges

with the base of the **styloid process**. About its middle the anterior and posterior oblique lines become confluent with it, and here, placed between them, is a rough elongated impression which marks the insertion of the pronator radii teres muscle. Above this, and on the outer surface of the neck, the supinator radii brevis muscle is inserted, whilst inferiorly this border is overlain by the tendons of the brachio-radialis and the extensor carpi radialis longior and brevior muscles.

The **anterior** or **flexor surface** (facies volaris) is crossed obliquely by a line which runs from the bicipital tubercle above, downwards, and outwards towards the middle of the outer border of the shaft. This, oftentimes called the **anterior oblique line**, serves for the attachment of the radial head of origin of the flexor sublimis digitorum muscle. Above it, the front of the bone has the fibres of the supinator radii brevis muscle inserted into it, whilst below and internal to it, extending as far down as the inferior limit of the middle third of the bone, is an extensive surface for the origin of the flexor longus pollicis muscle. In the lower fourth of the bone, where the shaft is broad and flat in front, there is a surface for the insertion of the pronator quadratus muscle which also extends back to the inter-osseous ridge.

The **extensor** or **posterior surface** (facies dorsalis) is also crossed by an oblique line, less distinct than the anterior. This serves to define the superior limit of the origin of the extensor ossis metacarpi pollicis muscle. Above this, the back of the neck and upper part of the shaft is overlain by the fibres of the supinator radii brevis, which become attached to this surface of the bone in its outer half. Below the posterior oblique line the posterior surface in the upper part of its inner half gives origin to the extensor ossis metacarpi pollicis, and the extensor brevis pollicis muscles in order from above downwards.

The **lower extremity**, which tends to be turned slightly forward when viewed from below, has a somewhat triangular form. Its inferior **carpal articular surface**, concave from before backwards, and slightly so from side to side, is divided into two facets by a slight antero-posterior ridge, best marked at its extremities where the anterior and posterior margins are notched; the external of these areas, of triangular shape, is for articulation with the scaphoid, whilst the inner, quadrilateral in form, is for the semilunar bone. The anterior border, prominent and turned forward, is rough at its edge, where it serves for the attachment of the anterior part of the capsule of the wrist joint. The posterior border is rough, rounded, and tubercular, and is grooved by many tendons; of these grooves the best marked is one which passes obliquely across its posterior surface. This is for the tendon of the extensor longus pollicis muscle. The outer lip of this groove is often very prominent, and forms an outstanding tubercle. To the ulnar side of this oblique groove there is a broad shallow furrow in which the tendons of the extensor communis digitorum and extensor indicis muscles are lodged, whilst to its outer side and between it and the styloid process, there is another broad groove, subdivided by a faint ridge into two, for the passage of the tendons of the extensor carpi radialis brevior and the extensor carpi radialis longior in that order from within outwards. The **styloid process** (processus styloideus) lies to the outer side of the inferior extremity; broad at its base, it becomes narrow and pointed below where by its inner cartilage-covered surface it forms the summit of the inferior triangular articular area. The outer surface of this process is crossed obliquely from above downwards and forwards by a shallow groove, the anterior lip of which is sharp and well marked, and serves to separate it from the anterior surface of the bone, whilst the posterior lip is often emphasised by a small tubercle above. The tendon of the brachio-radialis muscle is inserted into the upper part of either lip, and also spreads out on to the floor of the groove, whilst the tendons of the extensor ossis metacarpi pollicis and the extensor brevis pollicis muscles lie within the groove. To the tip of the styloid process is attached the external lateral ligament of the wrist. On the inner side of the lower extremity is placed the **sigmoid cavity** (incisura ulnaris) for the reception of the head of the ulna. Concave from before backwards, and plane from above downwards, it forms by its inferior margin a rectangular edge which separates it from the inferior carpal surface. To this edge the base of the triangular fibro-cartilage is attached, a structure which serves to separate the inferior articular surface of the head of

the ulna from the carpus. The anterior and posterior edges of the sigmoid cavity, more or less prominent, serve for the attachment of ligaments.

The proportionate length of the radius to the body height is as 1 is to 6·70–7·11.

Nutrient Foramina.—The openings of several small nutrient canals may be seen in the region of the neck. That for the shaft, which has an upward direction, is usually placed on the front of the bone, internal to the anterior oblique line, and from an inch and a half to two inches below the bicipital tubercle. The back of the lower extremity of the bone is pierced by many small foramina.

Connexions.—The radius articulates with the capitellum of the humerus in the flexed position of the elbow, with the ulna to its inner side by the superior and inferior radio-ulnar joints, and with the scaphoid and semilunar bones of the carpus below. Above, the head of the bone can be felt in the intermuscular depression on the outer side of the back of the elbow; here the bone is only covered by the skin, superficial fascia, and the thin common tendinous origin of the extensor muscles, as well as the ligaments which support it. Its position can best be ascertained by pronating and supinating the bones of the forearm, when the head will be felt rotating beneath the finger. The lower end of the bone is overlain in front and behind by the flexor and extensor tendons, but its general form can be readily made out. The styloid process lying to the outer side of the wrist in line with the extended thumb can easily be recognised; note that it reaches a lower level than the corresponding process of the ulna. The outer border of the lower third of the shaft can be distinctly felt, as here the bone is only overlain by tendons.

Architecture.—The neck is the narrowest part of the bone; here fracture may occur, though not commonly. The point at which the bone is usually broken is about one inch above the lower extremity. This is accounted for by the fact that the radius supports the hand at the radio-carpal articulation, and the shocks to which the latter is subjected, as in endeavouring to save oneself from falling, are naturally transmitted to the radius. On section, the medullary canal is seen to extend as high as the neck; below, it reaches to the level of the inferior fifth of the bone. Its walls are thick as compared with the diameters of the bone, particularly along the interosseous border, thus imparting rigidity to the curve of the shaft; these walls thin out above and below. Superiorly, the surface of the bicipital tubercle is formed of a thin shell of bone, which, however, thickens again where it passes on to the neck. The upper extremity is formed of spongy bone arranged in the form of arcades, reaching below the level of the bicipital tubercle internally, but not extending below the level of the neck externally. Beneath the capitellar articular surface there is a dense layer, thickest in the centre, and thinning towards the circumference; this is overlain by a very thin layer of less compact bone.

The inferior fifth of the shaft and lower extremity are formed of loose spongy bone arranged more or less longitudinally. Immediately subjacent to the carpal articular surface the tissue is more compact, and displays a striation parallel to the articular plane. The nutrient canal of the shaft pierces the anterior wall of the upper part of the medullary cavity obliquely from below upwards for the space of half an inch.

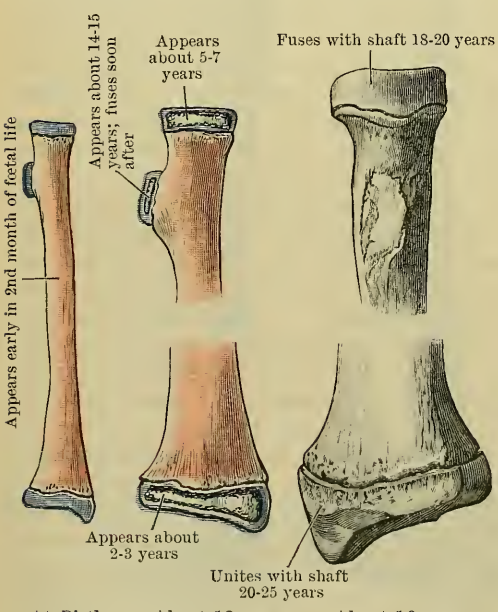


Fig. 144.—The Ossification of the Radius.

Variations.—Cases of congenital absence of the radius are recorded; in these the thumb is not infrequently wanting as well.

Ossification.—The centre for the shaft makes its appearance early in the second month of intrauterine life. At birth the shaft is well formed; its upper and lower extremities are capped with cartilage, and the bicipital tubercle is beginning to appear. A secondary centre appears in the cartilage of the lower extremity about the second or third year; this does not unite with the shaft until the twentieth or twenty-fifth year, somewhat earlier in the female. From this the carpal and ulnar articular surfaces are formed. The centre for the head appears from the fifth to the seventh year, and fuses with the neck about the age of eighteen or twenty. It forms the capitellar articular surface and combines with the neck to form the area for articulation with the small sigmoid cavity of the ulna. A scale-like epiphysis capping the summit of the bicipital tubercle has been described; this appears about the fourteenth or fifteenth year, and rapidly fuses with that process.

THE BONES OF THE HAND.

The bones of the hand, twenty-seven in number, may be conveniently divided into three groups:—

(1) The bones of the wrist or carpus—*eight* in number.
(2) The bones of the palm or metacarpus—*five* in number.
(3) The bones of the fingers and thumb or phalanges—*fourteen* in number.

The Carpus.

The **carpal bones** (ossa carpi) are arranged in two rows: the first, or proximal row, comprises from without inwards, the **scaphoid** (os naviculare), **semilunar** (os lunatum), **cuneiform** (os triquetrum), and **pisiform** (os pisiforme); the second or distal row includes the **trapezium** (os multangulum majus), **trapezoid** (os multangulum minus), **os magnum** (os capitatum), and **unciform** (os hamatum). Irregularly six-sided, each of these bones possesses non-articular palmar and dorsal surfaces. In addition, the marginal bones are non-articular along their ulnar and radial aspects according as they form the inner or outer members of the series.

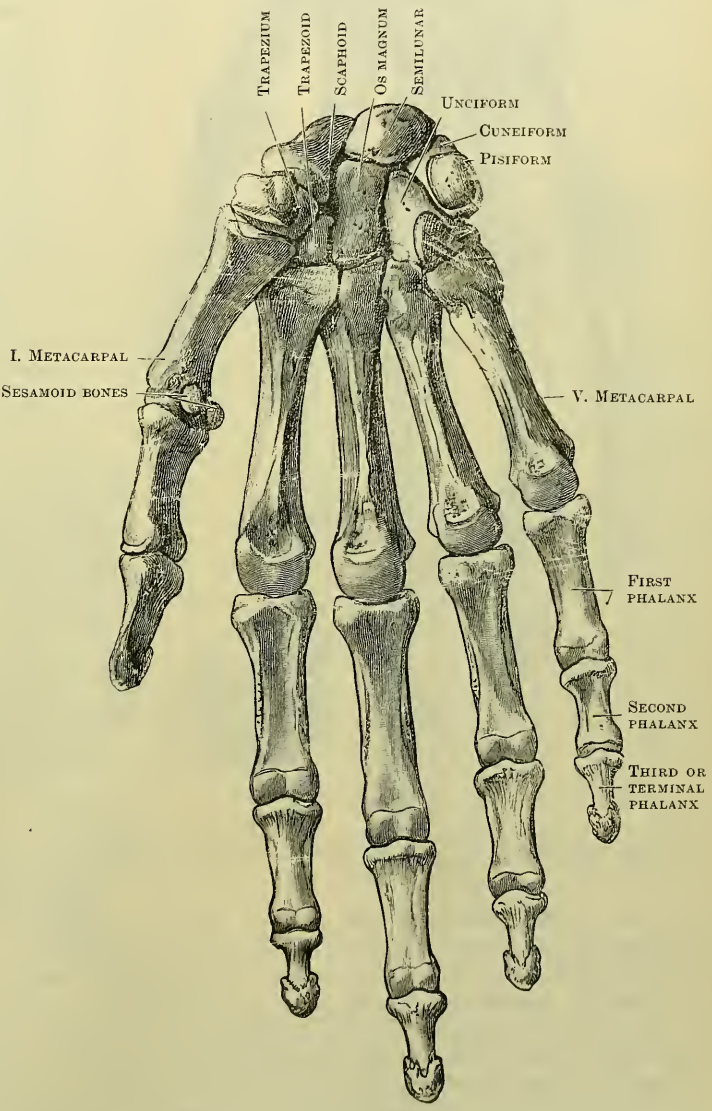


Fig. 145.—The Bones of the Right Wrist and Hand as seen from the Front.

Scaphoid Bone (os naviculare).—This is the largest as well as the outermost bone of the first row. Its *palmar surface*, rough for the attachment of ligaments, is irregularly triangular. The inferior external angle forms a projection called

the **tuberosity**; this can be felt at the base of the root of the thumb. Its *superior surface* is convex from side to side and before backwards for articulation with the radius. This area extends considerably over the posterior surface of the bone. Its *inferior surface* is convex from before backwards, and extends on to the dorsal aspect of the bone, slightly convex from side to side; it is divisible into two areas, the outer for articulation with the trapezium, the inner for the trapezoid. The *outer surface* is narrow and rounded and forms a non-articular border, which extends from the radial articular surface above to the tuberosity below. The *inner surface* is hollowed out in front for articulation with the head of the os magnum. Above this it displays a small semilunar-shaped facet for the semilunar bone. The *dorsal non-articular surface* lies between the radial articular surface above and the surface for the trapezium and trapezoid below. It is obliquely grooved for the attachment of the posterior ligaments of the wrist. The scaphoid articulates with five bones—the radius, the semilunar, the os magnum, the trapezoid, and the trapezium.

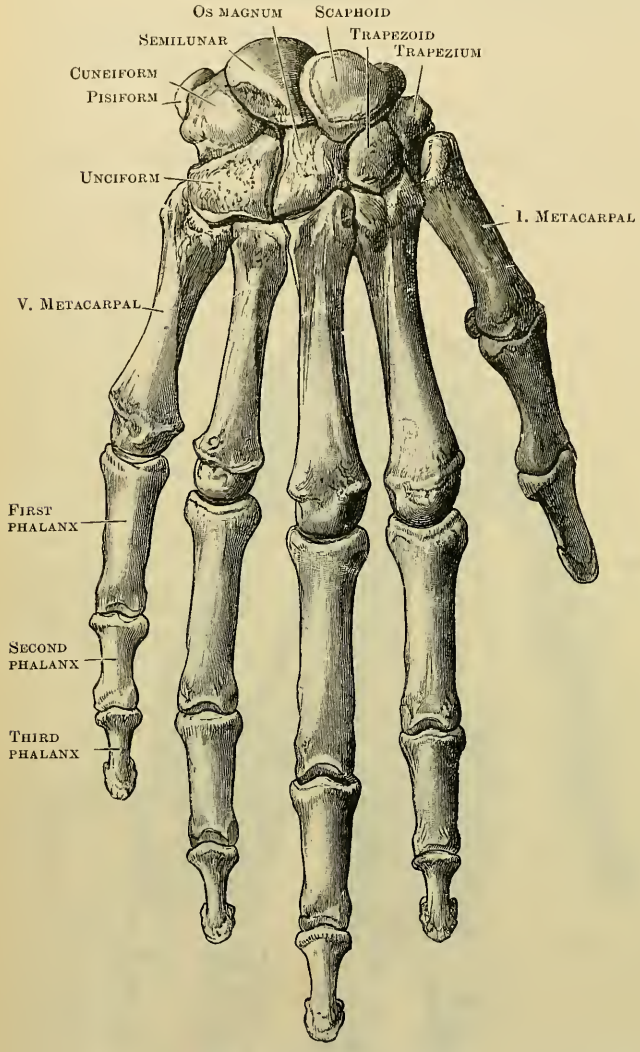


Fig. 146.—The Bones of the Right Wrist and Hand as seen from Behind.

Semilunar Bone (os lunatum).—So called from its deeply excavated form, the semilunar bone lies between the scaphoid on the outer side and the cuneiform on the inner. Its *palmar surface*, of rhombic form and considerable size, is rough for the attachment of ligaments; its *superior surface*, convex from side to side and from before backwards, articulates with the radius and in part with the under surface of the triangular fibro-cartilage of the wrist. Its *inferior aspect*, deeply hollowed from before backwards, is divided into two articular areas, of which the outer is the larger; this is for the head of the os magnum; the inner, narrow from side to side, articulates with the unciform. Its *external surface*, crescentic in shape, serves for articulation with the scaphoid, and also for the attachment of the interosseous ligaments which connect it with that bone. Its *inner surface*, of quadrilateral form, is cartilage-covered for articulation with the cuneiform, and the edge which separates this from the superior surface has attached to it the interosseous ligament which unites these two bones. The rough *dorsal non-articular surface* is much smaller than the palmar; by this means the front and back of the bone can readily be determined. The semilunar articulates

with five bones—the scaphoid, the radius, the cuneiform, the unciform, and the os magnum.

Cuneiform or Pyramidal Bone (os triquetrum).—This bone may be recognised by the small oval or circular facet on its anterior surface for the pisiform. This is placed towards the lower part of the *palmar surface*, which is elsewhere rough for ligaments. The bone is placed obliquely, so that its surfaces cannot be accurately described as inferior, superior, etc.; but for convenience of description, the method already adopted is adhered to. The *superior surface* has a convex rhombic surface for articulation with the under surface of the triangular fibro-cartilage in adduction of the hand, though ordinarily it does not appear to be in contact with that structure. To the ulnar side of this it is rough for ligaments. The *inferior surface* is elongated and concavo-convex from without inwards; here the bone articulates with the unciform. The *external surface*, broader in front than behind, articulates with the semilunar. The *inner surface*, rounded and rough, is confluent above and behind with the superior and dorsal aspects of the bone. The *dorsal surface*, rounded and smooth externally, is ridged and grooved internally for the attachment of ligaments. The cuneiform articulates with three bones, viz. the pisiform, the unciform, and the semilunar.

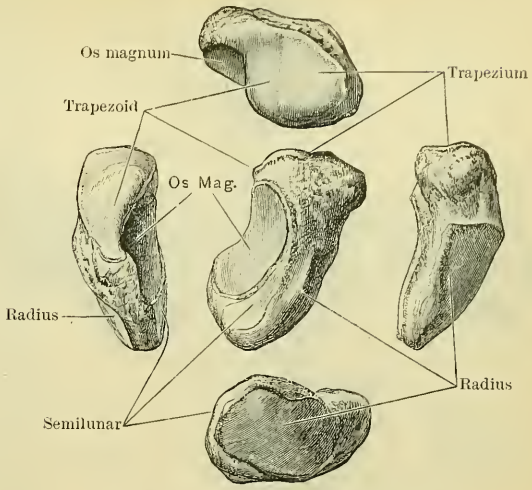


FIG. 147.—THE RIGHT SCAPHOID BONE.

NOTE.—The bone is represented in the centre of the figure in the position which it occupies in the hand viewed from the front. The views on either side, and above and below, represent respectively the corresponding surfaces of the bone turned towards the spectator.

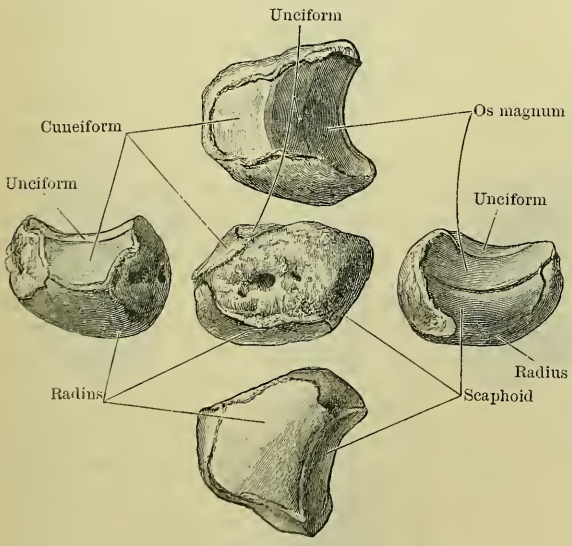


FIG. 148.—THE RIGHT SEMILUNAR BONE.

NOTE.—The bone is represented in the centre of the figure in the position which it occupies in the hand viewed from the front. The views on either side, and above and below, represent respectively the corresponding surfaces of the bone turned towards the spectator.

Pisiform bone (os pisiforme).—About the size and shape of a large pea, the pisiform bone rests on the anterior surface of the fore end of the cuneiform, with which it articulates by an oval or circular facet on its dorsal aspect. The rounded mass of the rest of the bone is non-articular, and inclines downwards and outwards so as to overhang the articular facet in front and externally. The mass of the bone is usually separated from the articular surface by a small but distinct groove. Into the summit of the bone the tendon of the flexor carpi ulnaris muscle is inserted, and here also the anterior annular ligament is attached.

Trapezium (os multangulum majus).—The trapezium is the outermost bone of the second row of the carpus. It may be readily recognised by the oval saddle-shaped facet on its inferior surface for articulation with the metacarpal bone of the thumb.

From its *palmar aspect* there rises a prominent **ridge**, within which is a groove along which the tendon of the flexor carpi radialis muscle passes. The ridge furnishes an attachment for the anterior annular ligament, as well as for some of the short muscles of the thumb. The *superior surface* has a half oval facet for the scaphoid, external to which it is rough, and becomes continuous with the non-articular *external aspect*, which serves for the attachment of ligaments. On its *inner surface* there are two facets; the upper is a half oval, concave from above downwards, and very slightly convex from before backwards, and is for articulation with the trapezoid. The lower, small and circular, and not always present, is for articulation with the outer side of the base of the second metacarpal bone. The *dorsal surface*, of irregular outline, is rough for the attachment of ligaments. The trapezium articulates with four bones, the scaphoid, trapezoid, and the first and second metacarpal bones.

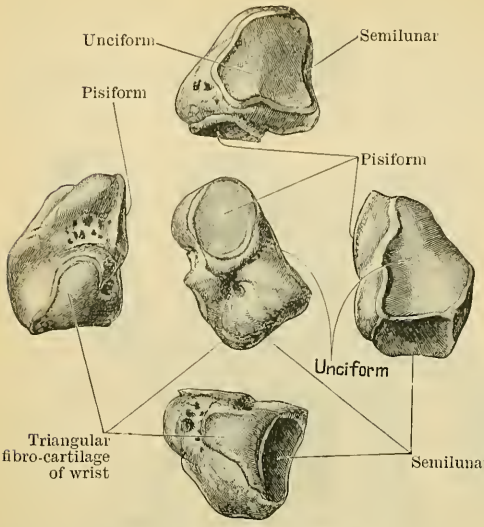


FIG. 149.—THE RIGHT CUNEIFORM BONE.

NOTE.—The bone is represented in the centre of the figure in the position which it occupies in the hand viewed from the front. The views on either side, and above and below, represent respectively the corresponding surfaces of the bone turned towards the spectator.

FIG. 150.—THE RIGHT PISIFORM BONE.

NOTE.—The figure to the left represents the palmar view of the bone; that to the right the dorsal view.

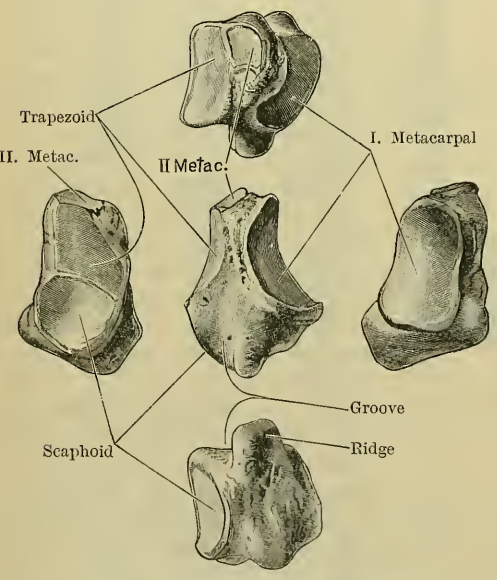


FIG. 151.—THE RIGHT TRAPEZIUM.

NOTE.—The bone is represented in the centre of the figure in the position which it occupies in the hand viewed from the front. The views on either side, and above and below, represent respectively the corresponding surfaces of the bone turned towards the spectator.

Trapezoid Bone (os multangulum minus).—With the exception of the pisiform, this is the smallest of the carpal bones. Its rough *palmar surface* is small and pentagonal in outline. By a small oblong surface on its *superior aspect* it articulates with the scaphoid. *Inferiorly*, by a somewhat saddle-shaped surface, it articulates with the base of the second metacarpal. Separated from this by a rough V-shaped impression, is the surface on the *outer side* for articulation with the trapezium; this appears as if obliquely grooved from before backwards and downwards. The *internal facet* for articulation with the os magnum is narrow from above downwards, and deeply curved from before backwards. The *dorsal surface* of the bone, which is rough and non-articular, is much larger than the palmar aspect. The mass of the bone, dorsally, is directed downwards and towards the ulnar side. The trapezoid articulates with four bones—the trapezium, scaphoid, os magnum, and the second metacarpal.

Os Magnum (os capitatum).—This is the largest of the carpal bones. Its *palmar surface* is rough and rounded. The *superior portion* of the bone forms the **head**, and is furnished with convex articular facets which fit into the hollows on the inferior surfaces of the scaphoid and semilunar; that for the latter is internal to and separated by a slight ridge from the scaphoid articular area. The *inferior surface*, narrow towards its palmar border and broad dorsally, is subdivided usually into three facets by two ridges—that towards the radial side is for the base of the second metacarpal; the middle facet is for the third metacarpal; whilst the innermost facet of the three, not always present, very small and placed near the dorsal side of the bone, is for the fourth metacarpal. The *outer side* of the body has an articular surface for the trapezoid, not infrequently separated from the scaphoid surface on the head by a rough line, to which the interosseous ligament connecting it with the scaphoid is attached. The *inner side* of the body has an elongated articular surface, usually deeply notched in front, or it may be divided anteriorly into a small circular area near the dorsal edge; and a larger posterior part. This latter articulates either singly or doubly with the unciform, the interosseous ligament which unites the two bones being attached either to the notch or to the surface separating the two articular facets. The *dorsal surface* is rough for ligaments; it is somewhat constricted below the head, the articular surface of which sweeps round its upper border.

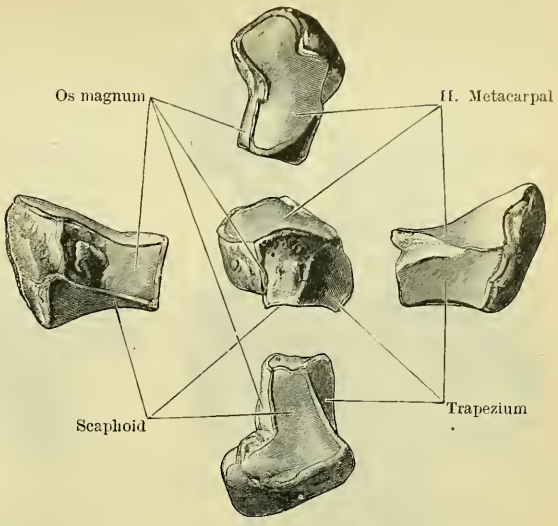


Fig. 152.—The Right Trapezoid.

Note.—The bone is represented in the centre of the figure in the position which it occupies in the hand viewed from the front. The views on either side, and above and below, represent respectively the corresponding surfaces of the bone turned towards the spectator.

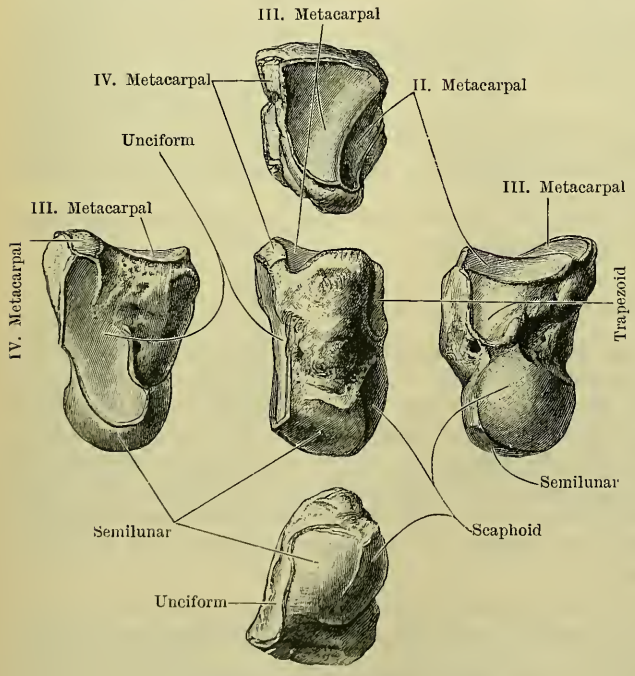


Fig. 153.—The Right Os Magnum.

Note.—The bone is represented in the centre of the figure in the position which it occupies in the hand viewed from the front. The views on either side, and above and below, represent respectively the corresponding surfaces of the bone turned towards the spectator.

The os magnum articulates with seven bones—the unciform, the semilunar, the scaphoid, the trapezoid, and the second, third, and fourth metacarpal bones; occasionally the fourth metacarpal does not articulate with the magnum.

Unciform Bone (os hamatum).—The unciform can be readily distinguished by

the **hook-like process** (hamulus) which projects from the lower and inner aspect of its anterior surface. To this is attached the anterior annular ligament as well as some of the fibres of origin of the short muscles of the little finger. The *ulnar side* of the unciform process is sometimes grooved by the deep branch of the ulnar nerve (Anderson, W., "Proc. Anat. Soc." *Journ. Anat. and Physiol.* vol. xxviii. p. 11). The *palmar surface*, rough for ligaments, is somewhat triangular in shape. *Superiorly* and *internally* there is an elongated articular surface for the cuneiform, convex above and concave below. The *outer aspect* of the bone is provided with a plane elongated facet, occasionally divided into two (see above) for articulation with the os magnum. Where the superior and external surfaces meet, the angle is blunt, and has a narrow facet which articulates with the semilunar. *Inferiorly* there are two articular facets separated by a ridge; these are slightly concave from before backwards, and are for articulation, the outer with the fourth, and the inner with the fifth metacarpal bone. The *dorsal surface*, more or less triangular in shape, is rough for ligaments.

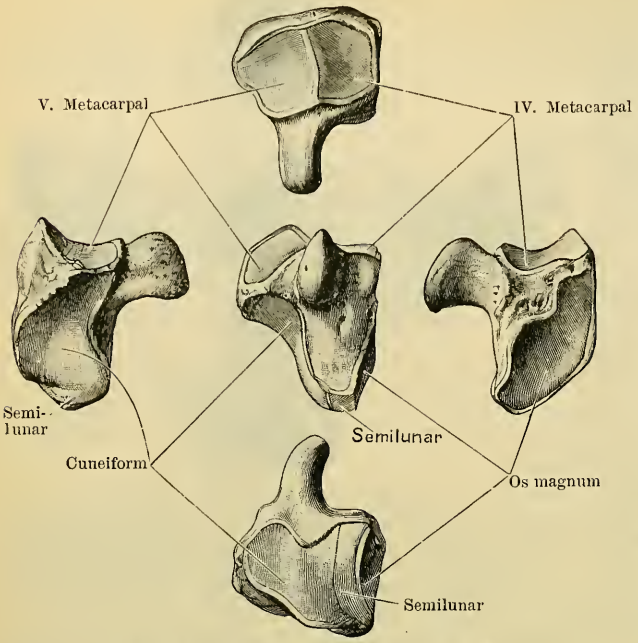


Fig. 154.—The Right Unciform Bone.

Note.—The bone is represented in the centre of the figure in the position which it occupies in the hand viewed from the front. The views on either side, and above and below, represent respectively the corresponding surfaces of the bone turned towards the spectator.

The unciform articulates with five bones—viz. the os magnum, semilunar, cuneiform, and the fourth and fifth metacarpals.

The Carpus as a Whole.

When the carpal bones are articulated together they form a bony mass, the dorsal surface of which is convex from side to side. Anteriorly they present a grooved appearance, concave from side to side. This arrangement is further emphasised by the forward projection, on the inner side, of the pisiform and hook of the unciform, whilst externally the tuberosity of the scaphoid and the ridge of the trapezium help to deepen the furrow by their elevation. To these four points the anterior annular ligament of the wrist is attached, which stretches across from side to side, and thus converts the furrow into a canal through which the flexor tendons pass to reach the fingers.

Architecture.—The bones are formed of fairly compact spongy tissue, surrounded by a thin shell of denser bone. They are very vascular, and their non-articular surfaces are pierced by many foramina.

Variations.—Increase in the number of the carpal elements is occasionally met with, and these have been ascribed to division of the scaphoid, semilunar, cuneiform, os magnum, trapezoid, and unciform. In the last-mentioned case the hook-like process persists as a separate ossicle; but the researches of Thilenius (*Morph. Arbeiten*, Bd. v. Heft 3, S. 462), together with the observations of Pfitzner, prove that all these supernumerary bones are but the persistence of independent cartilaginous elements which are met with in the hand of the human embryo between the second and fourth months, and which either disappear or become fused with adjacent elements. Of these the most interesting is the os centrale, first described by Rosenberg, and subsequently investigated by Henke, Leboucq, and others. This is met with almost invariably

as an independent cartilaginous element during the earlier months of fœtal life, and occasionally becomes developed into a distinct ossicle placed on the back of the carpus between the scaphoid and os magnum and the trapezoid. Its significance depends on the fact that it is an important component of the carpus in most mammals, and is met with normally in the orang and most monkeys. Ordinarily in man, as was pointed out by Lebouc̨q, it becomes fused with the scaphoid, where its presence is often indicated by a small tubercle, a condition which maintains in the chimpanzee, the gorilla, and the gibbons. Dwight has recently described a case in which there was an os subcapitulum in both hands. The ossicle lay between the base of the middle metacarpal bone and the os magnum with the trapezoid to its radial side. (*Anat. Anz.* vol. xxiv.) Further addition to the number of the carpal elements may be due to the separation of the styloid process of the third metacarpal bone and its persistence as a separate ossicle.

Reduction in the number of the carpus has been met with, but this is probably due to pathological causes. Morestin (*Bull. Soc. Anat. de Paris*, tome 71, p. 651), who has investigated the subject, finds that ankylosis occurs most frequently between the bases of the second and third metacarpal bones and the carpus, seldom or never between the carpus and the first metacarpal, or between the pisiform and cuneiform. G. Elliot Smith has recorded an instance of complete fusion between the semilunar and cuneiform bones in both wrists of a Soudanese negro. There was no evidence of any pathological change. (*Anat. Anz.* vol. xxiii. 1903.)

Fig. 155.—Radiograph of the Hand at Birth.

It will be noticed that whilst the primary centres for the metacarpus and phalanges are well ossified, the carpus is still entirely cartilaginous.

Compare this with Fig. 197, in which the tarsus is shown in part already ossified.

Ossification.—At birth the carpus is entirely cartilaginous. An exceptional case is figured by Lambertz, in which the centres for the os magnum and unciform were already present. The same authority states that it is not uncommon to meet with these centres in the second month after birth. According to Debierre (*Journ. de l'Anat. et de la Physiol.* vol. xxii. 1886, p. 285), ossification takes place approximately as follows:—

Os magnum	11 to 12 months.
Unciform	12 to 14 months.
Cuneiform	3 years.
Semilunar	5 to 6 years.
Trapezium	6 years.
Scaphoid	6 years.
Trapezoid	6 to 7 years.
Pisiform	10 to 12 years.

The same observer failed to note the appearance of a separate centre for the apophysis of the unciform, and records the occurrence of two centres for the pisiform.

The Metacarpus.

The **metacarpal bones** form the skeleton of the palm, articulating proximally with the carpus, whilst by their distal extremities or **heads** they support the bones of the fingers. Five in number, one for each digit, they lie side by side and slightly divergent from each other, being separated by intervals, termed interosseous spaces. Distinguished numerically from without inwards, they all display certain common characters; each possesses a **body** or shaft, a **base** or carpal extremity, and a **head** or phalangeal end.

The **shafts**, which are slightly curved towards the palmar aspect, are narrowest towards their middle. Their dorsal surface is marked by two divergent lines

which pass forward from the back of the base to tubercles on either side of the head. The surface included between the two lines is smooth and of elongated triangular form. On either side of these lines two broad shallow grooves wind spirally forward on to the palmar surface, where they are separated in front by a sharp ridge which is continuous with a somewhat triangular surface which corresponds to the palmar aspect of the base. The grooved surfaces on either side of the shaft furnish origins for the interossei muscles. Close to the palmar crest is the opening of the nutrient canal, which is directed towards the carpal extremity, except in the case of the first metacarpal bone.

Fig. 156.— First Right Metacarpal Bone.

The **head** (capitulum) is provided with a surface for articulation with the proximal phalanx. This area curves farther over its palmar than its dorsal aspect. Convex from before backwards and from side to side, it is wider anteriorly than posteriorly; notched on its palmar aspect, its edges form two prominent tubercles, which are sometimes grooved for the small sesamoid bones which may occasionally be found on the anterior surface of the joint. On either side of the head of the bone there is a deep pit, behind which is a prominent tubercle; to these are attached the lateral ligaments of the metacarpo-phalangeal joints.

The **bases** (basis), all more or less wedge-shaped in form, articulate with the carpus; they differ in size and shape according to their articulation.

Of the five metacarpal bones, the **first**, viz. that of the thumb, is the shortest and stoutest, the **second** is the longest, whilst the **third**, **fourth**, and **fifth** display a gradual reduction in length.

The four inner bones articulate by their bases with each other, and are united at their distal extremities by ligaments. They are so arranged as to conform to the hollow of the palm, being concave from side to side anteriorly, and convex posteriorly. The first metacarpal differs from the others in being free at its distal extremity, whilst its proximal end possesses only a carpal articular facet.

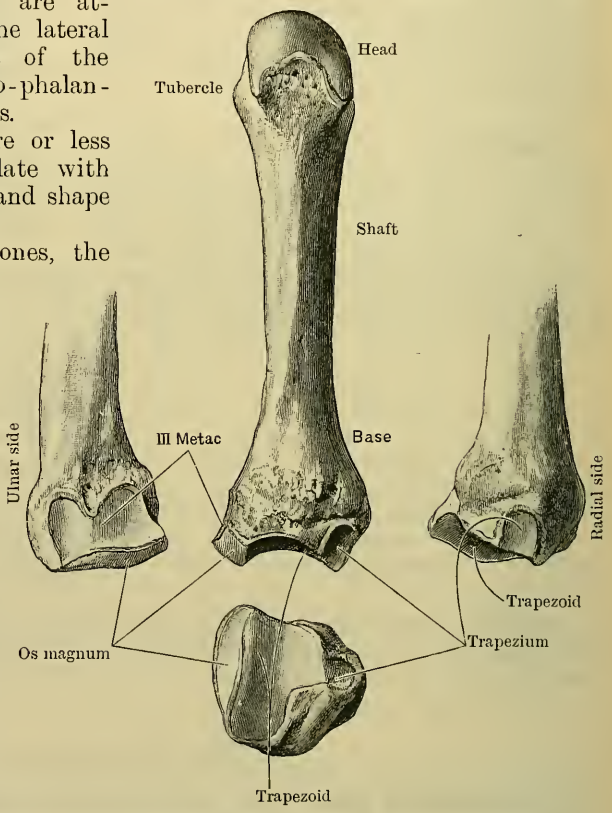


Fig. 157.—Second Metacarpal Bone.

Note.—The bone is represented in the centre of the figure in the position which it occupies in the hand viewed from the front. The views on either side, and below, represent respectively the corresponding surfaces of the bone turned towards the spectator.

The **first metacarpal bone** is the shortest and stoutest of the series. Its shaft is compressed from before backwards. Its head, of large size, is but slightly convex from side to side, and is grooved in front for the sesamoid bones. The base is provided with a saddle-shaped surface for articulation with the trapezium, and has no lateral facets. Externally there is a slight tubercle to which the

abductor longus pollicis or extensor ossis malacarpi pollicis muscle is attached. The canal for the nutrient artery is directed towards the head of the bone.

The **second metacarpal bone** is recognised by its length and its broad and deeply-notched base for articulation with the trapezoid. It has a small half-oval facet for the trapezium on the radial side of its base, whilst on its ulnar aspect it presents a narrow vertical strip for the os magnum, in front of which there are two half-oval surfaces for the third metacarpal. To the dorsal aspect of the base is attached the tendon of the extensor carpi radialis longior muscle, whilst the flexor carpi radialis is inserted in front.

The **third metacarpal bone** can usually be recognised by the pointed **styloid process** which springs from the back of its base, and is directed radial-wards. Superiorly there is a facet on the base for the os magnum.

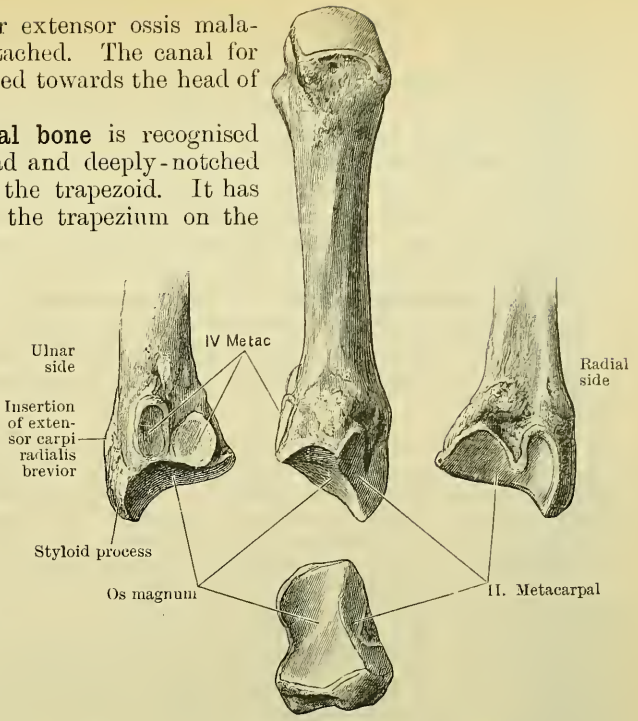


Fig. 158.—Third Metacarpal Bone.

Note.—The bone is represented in the centre of the figure in the position which it occupies in the hand viewed from the front. The views on either side, and below, represent respectively the corresponding surfaces of the bone turned towards the spectator.

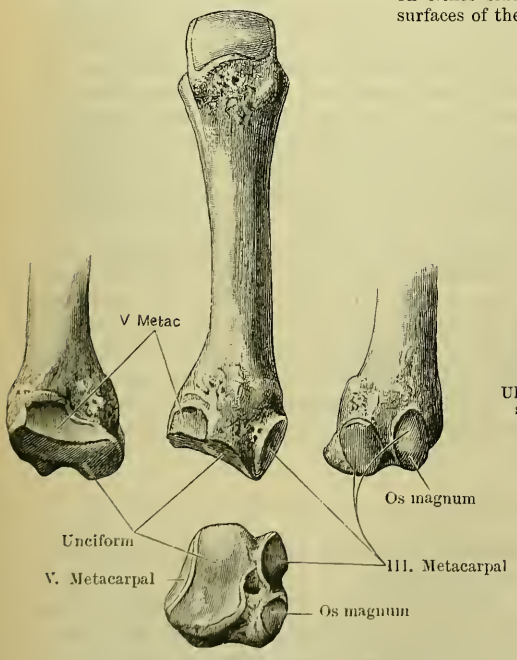


Fig. 159.—Fourth Metacarpal Bone.

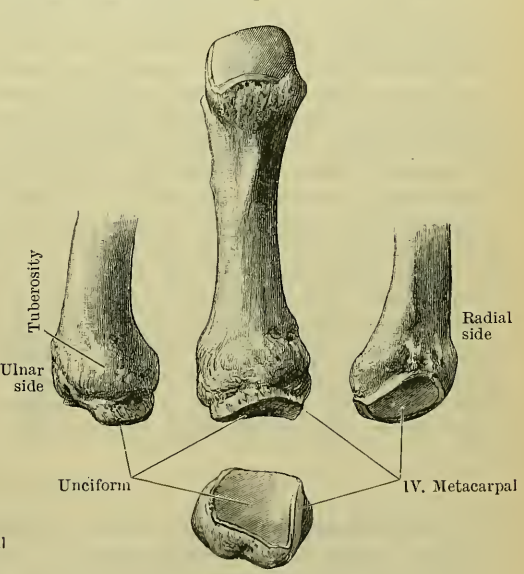


Fig. 160.—Fifth Metacarpal Bone.

Note.—The bone in each figure is represented in the centre of the figure in the position which it occupies in the hand viewed from the front. The views on either side, and below, represent respectively the corresponding surfaces of the bone turned towards the spectator.

To the radial side there are two half-oval facets for the second metacarpal. To the ulnar side there are usually two small oval or nearly circular facets for the

fourth metacarpal. The extensor carpi radialis brevior muscle is inserted into the back of the base.

The **fourth metacarpal bone** may be recognised by a method of exclusion. It is unlike either the first, second, or third, and differs from the fifth, which it resembles in size, by having articular surfaces on both sides of its base. Superiorly there is a quadrilateral surface on its base for articulation with the unciform. On its radial side there are usually two small oval facets for the third metacarpal. Of these facets the dorsal one not infrequently has a narrow surface for articulation with the os magnum. On the ulnar side there is a narrow articular strip for the base of the fifth metacarpal.

The **fifth metacarpal bone** can be recognised by its size and the fact that it has only one lateral articular facet on its base, namely, that on its radial side for the fourth metacarpal. The carpal articular surface is saddle-shaped, and there is a **tubercle** on the ulnar side of the base for the insertion of the extensor carpi ulnaris muscle.

As has been already pointed out, the openings of the arterial canals are usually seen on the palmar surfaces of the metacarpals, those of the four inner bones being directed upwards towards the base or carpal end, differing in this respect from that of the first metacarpal, which is directed downwards towards the head or phalangeal extremity. The opening of the latter canal usually lies to the ulnar side of the palmar aspect of the shaft.

Architecture.—Similar in arrangement to that of long bones generally, though it may be noted that the compact walls of the shaft are thicker in proportion to the length of the bone than in the other long bones of the upper extremity.

Variations.—As previously stated (*ante*, p. 209), the styloid apophysis of the third metacarpal bone appears as a separate ossicle in about 1·8 per cent of cases examined ("Fourth Annual Report of the Committee of Collect. Invest. Anat. Soc. Gt. Brit. and Ireland," *Journ. Anat. and Physiol.* vol. xxviii. p. 64). In place of being united to the third metacarpal, the styloid apophysis may be fused with either the os magnum or the trapezoid, under which conditions the base of the third metacarpal bone is without this characteristic process.

Ossification.—The metacarpal bones are developed from primary and secondary centres; but there is a remarkable difference between the mode of growth of the first and the remaining four inner metacarpals, for whilst the **shaft** and **head** of the first metacarpal are developed from the primary ossific centre, and its *base* from a secondary epiphysis, in the case of the second, third, fourth, and fifth metacarpals, the **shafts** and **bases** are developed from the primary centres, the *heads* in these instances being derived from the secondary epiphyses. In this respect, therefore, as will be seen hereafter, the metacarpal bone of the thumb resembles the phalanges in the manner of its growth, a circumstance which has given rise to considerable discussion as to whether the thumb is to be regarded as possessing three phalanges and no metacarpal, or one metacarpal and two phalanges. The primary centres for the shafts and bases of the second, third, fourth, and fifth metacarpals appear in that order during the ninth or tenth week of intrauterine life, some little time after the terminal phalanges have begun to ossify, that for the shaft and head of the metacarpal bone of the thumb a little later. At birth the shafts of the bones are well formed. The secondary centres from which the heads of the second, third, fourth, and fifth metacarpals and the base of the first are developed, appear about the third year, and usually completely fuse with the shafts about the age of twenty. There may be an independent centre for the styloid process of the third metacarpal, and there is usually a scale-like epiphysis on the head of the first metacarpal which makes its appearance about eight or ten, and rapidly unites with the head.

The Phalanges.

The **phalanges** or finger bones (phalanges digitorum manus) are fourteen in number—three for each finger, and two for the thumb.

Named numerically in order from the proximal toward the distal ends of the fingers, the **first phalanx** (phalanx prima), the longest and stoutest of the three, has a semi-cylindrical shaft which is curved slightly forwards. The palmar surface is flat, and bounded on either side by two sharp borders to which the sheath of the flexor tendons is attached. The dorsal surface, convex from side to side, is overlain by the extensor tendons. The proximal end, considerably enlarged, has a simple oval concave surface, which rests on the head of its corresponding metacarpal bone. On either side of this the bone is tubercular, and affords attachment to the lateral

ligaments of the metacarpo-phalangeal joint, and also to the interossei muscle. The distal end is much smaller than the proximal; the convex articular surface is divided into two condyles by a central groove running from before backward. The **second phalanx** (phalanx secunda) resembles the first in general form, but is of smaller size. It differs, however, in the form of its proximal articular surface, which is not a simple oval concavity, but is an oval area divided into two small, nearly circular concavities by a central ridge passing from before backwards; these articulate with the condyloid surfaces of the proximal phalanx. Into the margins of its palmar surface near the proximal end are inserted the split portions of the tendon of the flexor sublimis digitorum, whilst on the dorsal aspect of the proximal end the central slip of the extensor communis digitorum muscle is attached. The **third**, **terminal** or **ungual phalanx** (phalanx tertia), is the smallest of the three; it is easily recognised by the spatula-shaped surface on its distal extremity which supports the nail. The articular surface on its proximal end resembles that on the proximal end of the second phalanx, but is smaller. On the palmar aspect of this end of the bone there is a rough surface for the insertion of the tendon of the flexor profundus digitorum muscle. The dorsal surface of the same extremity has attached to it the terminal portions of the tendon of the extensor communis digitorum muscle. The phalanges of the thumb resemble in the arrangement of their parts the first and third phalanges of the fingers.

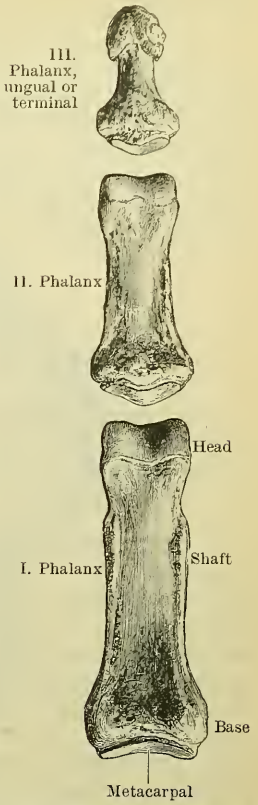


Fig. 161.—The Phalanges of the Fingers (palmar aspect).

The **arterial canals**, usually two in number, placed on either side of the palmar aspect and nearer the distal than the proximal end of the bone, are directed towards the finger-tips.

Architecture.—Each phalanx has a medullary cavity, the walls of the shaft being formed of dense compact bone, especially thick along the dorsal aspect. The extremities are made up of spongy bone within a thin dense shell.

Variations.—Several instances have been recorded of cases in which there were three phalanges in the thumb. Bifurcation of the terminal phalanges has occasionally been met with, and examples of suppression of a phalangeal segment or its absorption by another phalanx have also been described (Hasselwander, *Zeits. F. Morph. u. Anthr.*, vol. vi. 1903).

Ossification.—The phalanges are ossified from primary and secondary centres. From the former, which appear as early as the ninth week of fœtal life, the shaft and distal extremities are developed; whilst the latter, which begin to appear about the third year, form the proximal epiphyses which unite with the shafts from eighteen to twenty. Dixey (*Proc. Roy. Soc.*, xxx. and xxxi.) has pointed out that the primary centre in the ungual phalanges commences to ossify in the distal part of the bone rather than towards the centre of the shaft. This observation has been confirmed by Lambertz, who further demonstrates the fact that ossification commences earlier in the distal phalanges than in any of the other bones of the hand. Of the other phalanges, those of the first row, beginning with that of the third finger, next ossify, subsequent to the appearance of ossific centres in the shafts of the metacarpal bones, whilst

Fig. 162.—Radiographs of Fœtal Hands.

A. About 10 weeks. Here the ossific nuclei of the terminal phalanges and the four inner metacarpal bones are seen.
B. A little later. The centre for the metacarpal bone of the thumb is now appearing, and the centres for the first phalanges of the index and middle fingers are clearly seen.
C. About the beginning of the third month. The centres for all the first row of phalanges are now distinct, and the centres for the second phalanges of the index, middle, and ring fingers have made their appearance.
D. Between the third and fourth month. The primary centres for all the phalanges and metacarpus are now well developed.

the second or intermediate row of the phalanges is the last to ossify about the end of the third month.

Sesamoid Bones.

Two little oval nodules (ossa sesamoidea), which play in grooves on the palmar aspect of the articular surface of the head of the first metacarpal bone, are constantly met with in the tendons and ligaments of that metacarpo-phalangeal articulation. Similar nodules, though of smaller size, are sometimes formed in the corresponding joints of the other fingers, more particularly the index and little finger; as Thilenius has pointed out (*Morph. Arbeiten*, vol. v.), these are but the persistence of cartilaginous elements which have a phylogenetic interest.

THE LOWER LIMB.

THE PELVIC GIRDLE AND THE LOWER EXTREMITY.

The **pelvic girdle** is formed by the articulation of the two haunch bones with the sacrum behind, and their union with each other in front, at the joint called the symphysis pubis.

The Innominate Bone.

The **innominate** or haunch bone (os coxæ) is the largest of the flat bones of the skeleton. It consists of three parts—the **ilium**, the **ischium**, and the **pubis**—primarily distinct, but fused together in the process of growth to form one large irregular bone. The coalescence of these elements takes place in and around the **acetabulum**, a large circular articular hollow which is placed on the outer side of the bone. The expanded wing-like part above this is the ilium; the stout V-shaped portion below and behind it constitutes the ischium; while the >-shaped part to the inner side, and in front and below, forms the pubis. The two latter portions of the bone enclose between them a large aperture of irregular outline, called the **thyroid** or **obturator** foramen (foramen obturatorum), which is placed in front and below, and to the inner side of the acetabulum.

The **ilium**, almost a quadrant in form, consists of an expanded plate of bone, having a curved superior border, the **iliac crest** (crista iliaca). Viewed from the side, this forms a curve corresponding to the circumference of the circle of which the bone is the quadrant; viewed from above, however, it will be seen to display a double bend—convex anteriorly and externally, and concave posteriorly and externally. The iliac crest is stout and thick, and for descriptive purposes is divided into an outer lip (labium externum), an inner lip (labium internum), and an intermediate surface (linea intermedia) which is broad behind, narrowest about its middle, and wider again in front. About $2\frac{1}{2}$ inches from the anterior extremity of the crest the outer lip is usually markedly prominent and forms a projecting tubercle, which can readily be felt in the living. Attached to these surfaces and lips anteriorly are the muscles of the flank, whilst from them posteriorly the latissimus dorsi, quadratus lumborum, and erector spinæ muscles derive their origins. The crest ends in front in a pointed process, the **anterior superior iliac spine** (spina iliaca anterior superior). To this the outer extremity of Poupart's ligament is attached, as well as the sartorius muscle, which also arises from the edge of bone immediately below it, whilst from the same process and from the anterior end of the outer lip of the iliac crest externally the tensor fasciæ femoris muscle takes origin.

The **anterior border** of the ilium stretches from the anterior superior iliac spine to the margin of the acetabulum below. Above, it is thin; but below, it forms a thick tubercular process, the **anterior inferior iliac spine** (spina iliaca anterior inferior). From this the rectus femoris muscle arises, whilst the stout fibres of the ilio-femoral ligament of the hip-joint are attached to it immediately above the acetabular margin. Posteriorly, the crest terminates in the **posterior superior iliac spine** (spina iliaca posterior superior). Below this, the posterior border of the bone is sharp and irregularly notched terminating in a prominent angle, the **posterior**

inferior iliac spine (spina iliaca posterior inferior), in front of which the edge of the bone becomes thick and rounded, and forms a wide notch which sweeps forwards and downwards to join the mass of bone behind the acetabulum, where it becomes fused with the ischium; this is called the **ilio-sciatic** or **great sciatic notch** (incisura ischiadica major).

The ilium has two surfaces, an inner and an outer. The *external surface* is

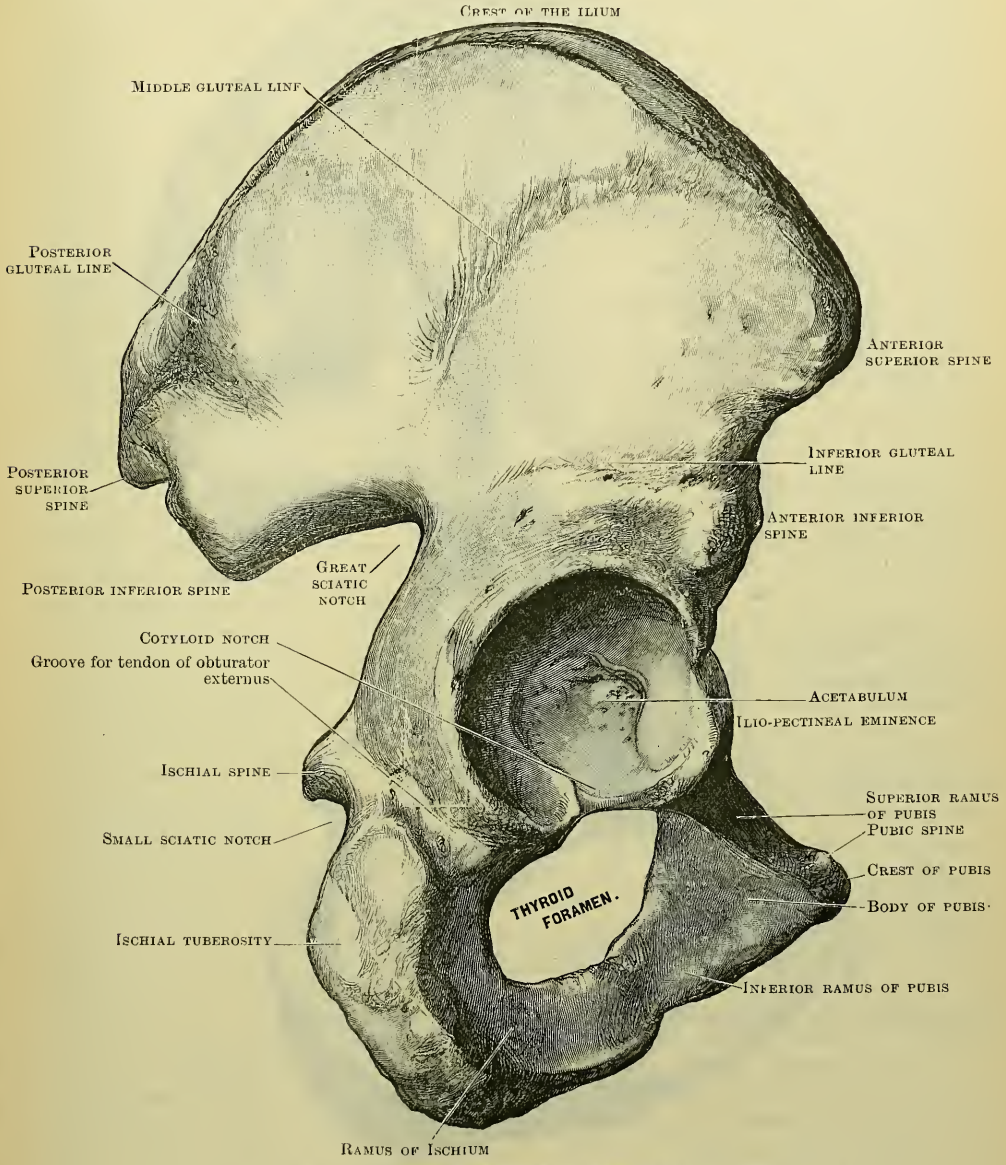


Fig. 163.—The Right Innominate Bone as seen from the Outer Side.

divided into two parts, viz. a lower acetabular, and an upper gluteal part. The lower forms a little less than the upper two-fifths of the acetabular hollow, and is separated from the larger gluteal surface above by the upper prominent margin of the articular cavity. The **gluteal surface**, broad and expanded, is concavo-convex from behind forward. It is traversed by **three** rough **curved lines**, well seen in strongly developed bones, but often faint and indistinct in feebly marked specimens. Of these the **inferior curved line** (linea glutæa inferior) curves backwards from a point immediately above the anterior inferior spine towards the ilio-sciatic

notch posteriorly; the bone between this and the acetabular margin is marked by a rough shallow groove, from which the reflected head of the rectus femoris muscle arises. The **middle curved line** (linea glutæa anterior) commences at the crest of the ilium, about one inch and a half behind the anterior superior iliac spine, and

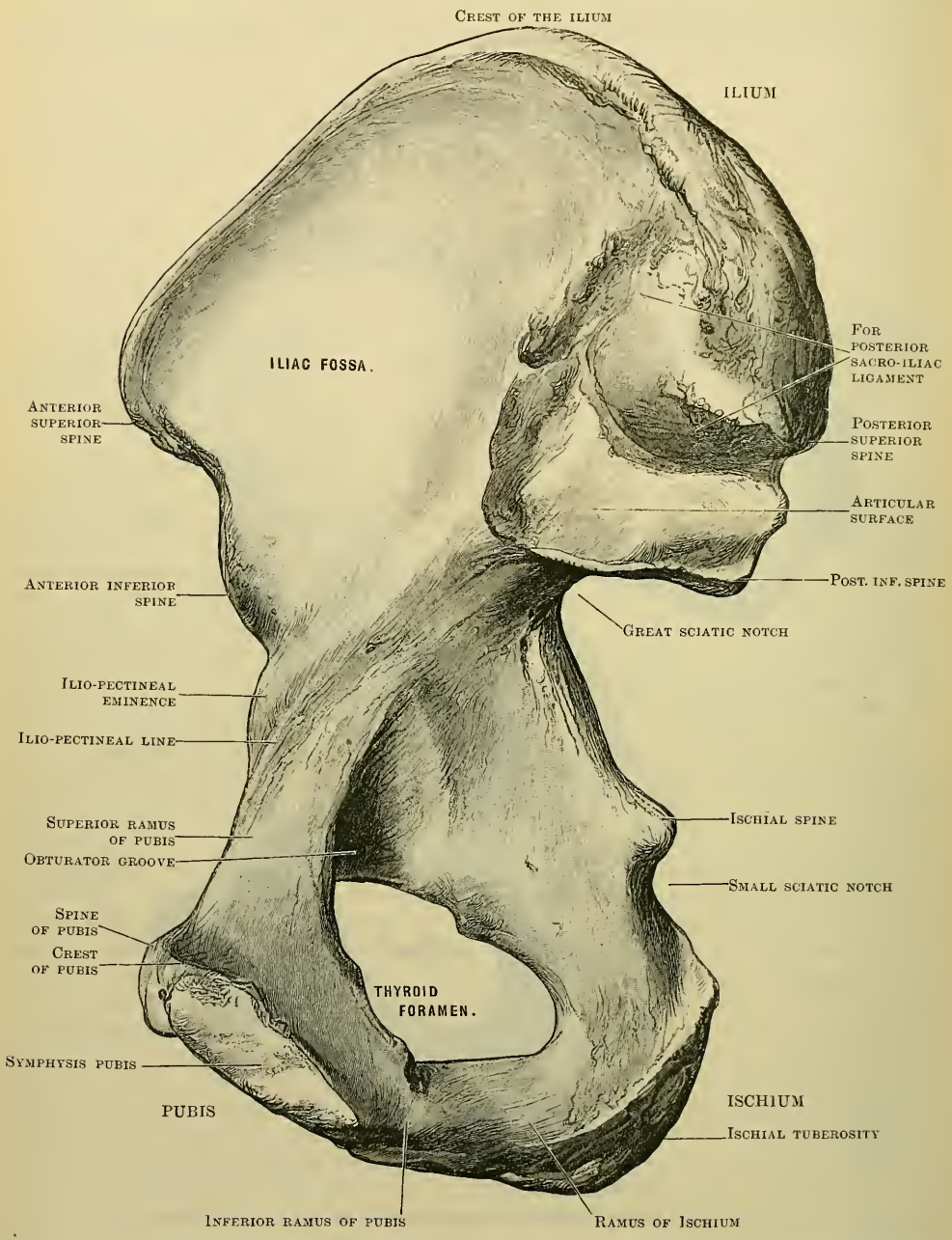


Fig. 164.—The Right Innominate Bone (Inner Aspect).

sweeps backwards and downwards towards the upper and posterior part of the ilio-sciatic notch. The surface between this line and the preceding furnishes an extensive origin for the gluteus minimus muscle. The **posterior** or **superior curved line** (linea glutæa posterior) leaves the iliac crest about two and a half inches in front of the posterior superior iliac spine, and bends downwards and slightly forwards in a direction anterior to the posterior inferior spine. The area between this and the middle curved line is for the origin of the gluteus medius muscle, whilst the rough

surface immediately above and behind it is for some of the fibres of origin of the gluteus maximus muscle.

The *inner surface* of the ilium is divided into two areas which present very characteristic differences. The **posterior** or **sacral part**, which is rough, displays in front a somewhat smooth, auricular surface (facies auricularis) which is cartilage-coated in the recent condition, and articulates with the sacrum. Above and behind this there is an elevated irregular area, the **tuberosity** (tuberositas iliaca), which is here and there deeply pitted for the attachment of the strong posterior sacro-iliac ligaments. Above this the bone becomes confluent with the inner lip of the iliac crest, and here it affords an origin to the erector spinæ and multifidus spinæ muscles. The anterior part of the inner aspect of the bone is smooth and extensive; it is subdivided by an oblique ridge, called the **ilio-pectineal line** (linea arcuata), which passes forwards and downwards from the most prominent point of the auricular surface towards the inner side of the ilio-pectineal eminence which is placed just above and in front of the acetabulum, and marks the fusion of the ilium with the pubis. Above this the bone forms the shallow **iliac fossa** (fossa iliaca), from the floor of which the iliacus muscle arises, whilst leading from the fossa, below and in front, there is a shallow furrow, passing over the superior acetabular margin, between the anterior inferior iliac spine on the outer side and the ilio-pectineal eminence internally, for the lodgment of the tendinous and fleshy part of the ilio-psoas muscle. If held up to the light the floor of the deepest part of the iliac fossa will be seen to be formed of but a thin layer of bone. A nutrient foramen of large size is seen piercing the bone towards the hinder part of the fossa. Below and behind the ilio-pectineal line the inner surface of the ilium forms a small portion of the wall of the true pelvis; the bone here is smooth, and rounded off posteriorly into the ilio-sciatic notch, where it becomes confluent with the inner aspect of the ischium. Just anterior to the ilio-sciatic notch there are usually the openings of one or two large vascular foramina. From this surface arise some of the posterior fibres of the obturator internus muscle.

The **ischium** constitutes the lower and hinder part of the innominate bone. Superiorly its **body** (corpus) forms somewhat more than the inferior two-fifths of the acetabulum together with the bone supporting it behind and within. Below this, the **superior ramus** passes downwards and backwards as a stout three-sided piece of bone, from the inferior extremity of which a compressed bar of bone, called the **inferior ramus**, extends forwards at an acute angle. This latter unites in front and above with the descending ramus of the pubis, and encloses the aperture called the obturator foramen.

Superiorly, and on the outer aspect of the ischium, the acetabular surface is separated from the bone below by a sharp and prominent margin, which is, however, deficient in front, where it corresponds to the **cotyloid notch** (incisura acetabuli) leading into the articular hollow; the floor of this notch is entirely formed by the ischium. Below the prominent acetabular margin there is a well-marked groove in which the tendon of the obturator externus lies. Beneath this the antero-external surface of the superior and inferior rami furnish surfaces for the attachments of the obturator externus, quadratus femoris, and adductor magnus muscles. The postero-external surface of the ischium forms the convex surface on the back of the acetabulum. The inner border of this is sharp and well defined, and is confluent above with the border of the ilium, which sweeps round the great or ilio-sciatic notch. From this border, on a level with the lower edge of the acetabulum, there springs a pointed process, the **spine** (spina ischiadica), to which is attached the lesser sacro-sciatic ligament and the superior gemellus muscle. Inferior to this, the postero-external surface narrows rapidly, its inner border just below the spine being hollowed out to form the **small sciatic notch** (incisura ischiadica minor). The lower part of this surface and the angle formed by the two rami are capped by an irregularly rough pyriform mass called the **tuberosity** (tuber ischii). This is divided by an oblique ridge into two areas, the upper and outer for the tendon of origin of the semimembranosus muscle, the lower and inner for the conjoined heads of the biceps and semitendinosus muscles. Its prominent inner lip serves for the attachment of the great sacro-sciatic ligament, whilst its outer edge furnishes an

origin for the quadratus femoris muscle; in front and below, the adductor magnus muscle is attached to it.

The *inner surface* of the body and superior ramus of the ischium form in part the wall of the true pelvis. Smooth and slightly concave from before backwards, and nearly plane from above downwards, it is widest opposite the level of the ischial spine. Below this, its posterior edge is rounded and forms a groove leading to the small sciatic notch, along and over which the tendon of the obturator internus passes. To part of this surface the fibres of the obturator internus are attached, whilst the inner aspect of the spine supplies points of origin for the coccygeus and levator ani muscles, as well as furnishing an attachment to the "white line" of the pelvic fascia. The inner surface of the inferior ramus of the ischium is smooth, and so rounded that its inferior edge tends to be everted. To this, as well as to its margin, is attached the crus penis, together with the ischio-cavernosus, obturator internus, transversus perinei, and compressor urethræ muscles. In the female, structures in correspondence with these are also found.

The fore-part of the innominate bone is formed by the **pubis**; it is by means of the union of this bone with its fellow of the opposite side that the pelvic girdle is completed in front.

The **pubis** (os pubis) consists of two rami—a **superior, ascending,** or **horizontal** (ramus superior ossis pubis), and an **inferior** or **descending** (ramus inferior ossis pubis). The broad part of the bone formed by the fusion of these two rami is the **body.**

The body is sometimes described as that part of the bone which enters into the formation of the acetabulum, but the English nomenclature has here been followed.

The **body of the pubis** has two surfaces. Of these the *inner* or *posterior* is smooth, and forms the fore-part of the wall of the true pelvis; hereto are attached the levator ani muscle and puboprostatic ligaments. The *anterior* or *external surface* is rougher, and furnishes origins for the gracilis, adductor longus, adductor brevis, and some of the fibres of the obturator externus muscles. The *inner border* is provided with an elongated oval cartilage-covered surface by means of which it is united to its fellow of the opposite side, the joint being called the **symphysis pubis.** The *upper border,* thick and rounded, projects somewhat, so as to overhang the anterior surface. It is called the **crest.** Internally this forms with the inner border or symphysis the **angle,** whilst externally it terminates in a pointed process, the **spine** (tuberculum pubicum). From the crest arise the rectus abdominis and pyramidalis muscles, and to the spine is attached the inner end of Poupart's ligament. Passing upwards and outwards from the outer side of the body towards the acetabulum, of which it forms about the anterior fifth, is the **superior ramus** (ramus superior). This has three surfaces: an antero-superior, an antero-inferior, and an internal or posterior. The *antero-superior surface* is triangular in form. Its apex corresponds to the pubic spine; its anterior inferior border to the **obturator crest** (crista obturatoria), leading from the spine to the upper border of the cotyloid notch; whilst its sharp postero-superior border trends upwards and outwards from the spine, and is continuous with the iliac portion of the ilio-pectineal line just internal to the ilio-pectineal eminence, forming as it passes along the superior ramus the pubic portion of that same line (pecten ossis pubis). On this line, just within the ilio-pectineal eminence, there is often a short, sharp crest which marks the insertion of the psoas parvus. The base of the triangle corresponds to the ilio-pectineal eminence above and the upper margin of the cotyloid notch below. Slightly hollow from side to side, and convex from before backwards, this surface provides an origin for, and is in part overlain by, the pectineus muscle. The *internal* or *posterior surface* of the superior ramus is smooth, concave from side to side, and slightly rounded from above downwards; by its sharp inferior curved border it completes the thyroid foramen, as seen from behind. The *antero-inferior surface* forms the roof of the broad obturator groove (sulcus obturatorius) which passes obliquely downwards and forwards between the lower margin of the antero-superior surface in front and the inferior sharp border of the internal surface behind. The **inferior** or **descending ramus of the pubis** (ramus inferior) passes downwards and outwards from the lower part of the body.

Flattened and compressed, it unites with the inferior ramus of the ischium, and thus encloses the thyroid foramen, whilst in correspondence with its fellow of the opposite side it completes the formation of the pubic arch. *Anteriorly* it furnishes origins for the gracilis, adductor brevis, and adductor magnus muscles, as well as some of the fibres of the obturator externus muscle. Its *inner surface* is smooth, whilst its lower border, rounded or more or less everted, has attached to it the fore-part of the crus penis and the subpubic ligament.

The **acetabulum** or **cotyloid cavity** is the nearly circular hollow in which the head of the thigh bone fits. As has been already stated, it is formed by the fusion of the ilium and ischium and pubis in the following proportions: the ilium a little less than two-fifths, the ischium somewhat more than two-fifths, the pubis constituting the remaining one-fifth. It is so placed as to be directed downwards, outwards, and forwards, and is surrounded by a prominent margin, to which the capsule and cotyloid ligament of the hip-joint are attached. Opposite the obturator foramen this margin is interrupted by the **cotyloid notch** (incisura acetabuli); immediately external to the ilio-pectineal eminence the margin is slightly hollowed, whilst occasionally there is a feeble notching of the border above and behind. These irregularities in the outline of the margin correspond to the lines of fusion of the ilium and pubis, and the ilium and ischium respectively. The floor of the acetabulum is furnished with a horseshoe-shaped articular surface, which lines the circumference of the hollow, except in front, where it is interrupted by the cotyloid notch. It is broad above; narrower in front and below. Within this articular surface there is a more or less circular rough area (fossa acetabuli) continuous in front and below with the floor of the cotyloid notch. This, somewhat depressed below the surface of the articular area, lodges a quantity of fat, and provides accommodation for the interarticular ligament of the joint. As may be seen by holding the bone up to the light, the floor of this part of the acetabulum is not usually of great thickness. The major part of the non-articular area is formed by the ischium, which also forms the floor of the cotyloid notch.

The **thyroid** or **obturator foramen** (foramen obturatum) lies in front of, below, and internal to the acetabulum. The margins of this opening, which are formed in front and above by the pubis, and behind and below by the ischium, are sharp and thin, except above, where the under surface of the superior ramus of the pubis is channelled by the obturator groove. Below, and on either side of this groove, two tubercles can usually be seen. The one, situated on the edge of the ischium, just in front of the cotyloid notch, is named the **posterior obturator tubercle** (tuberculum obturatorium posterius); the other, placed on the lower border of the inner surface of the superior ramus of the pubis, is called the **anterior obturator tubercle** (tuberculum obturatorium anterius). Between these two tubercles there passes a ligamentous band, which converts the groove into a canal along which the obturator vessels and nerve pass. Elsewhere in the fresh condition the obturator or thyroid membrane stretches across the opening from margin to margin. The form of the foramen varies much, being oval in some specimens, in others more nearly triangular; its relative width in the female is greater than the male.

Nutrient foramina for the ilium are seen on the floor of the iliac fossa, just in front of the sacro-auricular surface; on the pelvic aspect of the bone, close to the great sciatic notch; and on the gluteal surface externally, near the centre of the middle curved line. For the ischium, on its pelvic surface, and also externally on the groove below the acetabulum. For the pubis, on the surface of the body, and deeply also from the acetabular fossa.

Connexions.—The innominate bone articulates with the sacrum behind, with the femur to the outer side and below, and with its fellow of the opposite side internally and in front. Each of its three parts comes into direct relation with the surface. Above, the iliac crest assists in forming the iliac furrow, which serves to separate the region of the flank from that of the buttock. In front, the anterior superior iliac spine forms a definite landmark; whilst behind, the posterior superior iliac spines will be found to correspond with dimples situated on either side of the middle line of the root of the back. The symphysis, the crest, and spine of the pubis can all be distinguished in front, though overlain by a considerable quantity of fat, whilst the position of the tuberosities of the ischia, when uncovered by the great gluteal muscles in the flexed position of the thigh, can readily be ascertained. In the perineal region the outline of the pubic and ischial rami can easily be determined by digital examination.

Architecture.—As a flat bone the os innominatum consists of spongy tissue between two compact external layers. These latter vary much in thickness, being exceptionally stout along the ilio-pectinal line and the floor of the iliac fossa immediately above it. The gluteal aspect of the ilium is also formed by a layer of considerable thickness. The spongy tissue is loose and cellular in the thick part of the ilium and in the body of the ischium; absent where the floor of the iliac fossa is formed by the coalescence of the thin dense confining layers; fine grained and more compact in the tuberosity of the ischium, the iliac crest, and the floor of the acetabulum, in which latter situation it is striated by fibres which are directed radially to the surface of that hollow, these again being crossed at right angles by others which are arranged circumferentially. This spongy tissue forms a more compact layer over the surface of the upper and back portion of the acetabular articular area. The bottom of the floor of the acetabulum varies in thickness; in most cases it is thin, and in exceptional instances the bone is here deficient. The same condition has been met with in the iliac fossa, where absorption of the thin bony plate has taken place.

Variations.—Some of the anomalies met with in the haunch bone are due to ossification of the ligaments connected with it; in other cases they depend on errors of development. Failure of union between the pubic and ischial rami has also been recorded. Cases have occurred where the obturator groove has been bridged across by bone, and one case is noted of absence of the cotyloid notch on the acetabular margin. In rare cases the os acetabuli (see Ossification) remains as a separate bone.

Ossification commences in the ilium about the ninth week of intrauterine life; about the fourth month a centre appears below the acetabulum for the ischium, the pubis being developed from a centre which appears in front of the acetabulum about the fifth or sixth month. At birth the form of the ilium is well defined; the body and part of the tuberosity of the ischium are ossified, as well as the horizontal ramus and part of the body of the pubis. All three parts enter into the formation of the sides of the acetabulum, and by the third year have converged to form the bottom of that hollow, being separated from each other by a triradiate piece of cartilage, in which, about the twelfth year, independent ossific centres make their appearance, which may or may not become fused with the adjacent bones. In the latter case they unite to form an independent ossicle, the os acetabuli, which subsequently fuses with and forms the acetabular part of the pubis. By the age of sixteen the ossification of the acetabulum is usually completed, whilst the rami of the ischium and pubis commonly unite about the tenth year. Secondary centres, six in number, make their appearance about the age of puberty, and are found in the following situations: one for the anterior inferior iliac spine, one for the iliac crest and the anterior and posterior superior iliac spines, a scale-like epiphysis over the tuberosity of the ischium, a separate epiphysis for the spine of the ischium, (?) a point for the spine and another for the angle of the pubis. Fusion between these and the primary centres is usually complete between the twenty-second and twenty-fifth years.

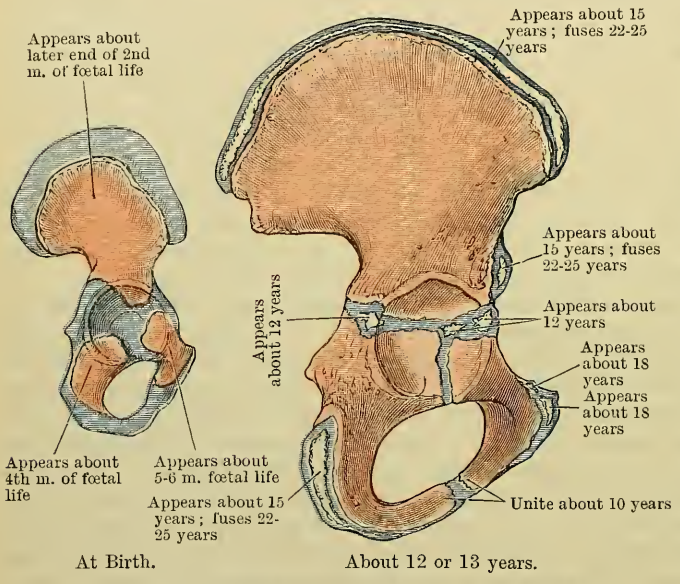


Fig. 165.—Ossification of the Innominate Bone.

Parsons (*Journ. Anat. and Physiol.*, vol. xxxvii. p. 315) regards the ischial epiphysis as the homologue of the hypo-ischium in reptiles, and suggests that the epiphysis over the angle of the pubis may represent the epipubic bone of marsupials.

The Pelvis.

The **pelvis** is formed by the union of the innominate bones with each other in front, and with the sacrum behind. In man the dwarfed caudal vertebræ

(coccygeal) are curved forwards and so encroach upon the limits of the pelvic cavity inferiorly. The pelvis is divided into two parts by the ilio-pectineal lines, which curve forwards from the upper part of the lateral masses of the sacrum behind, to the roots of the spines of the pubes in front. The part above is called the **false pelvis** (pelvis major), and serves by the expanded iliac fossæ to support the

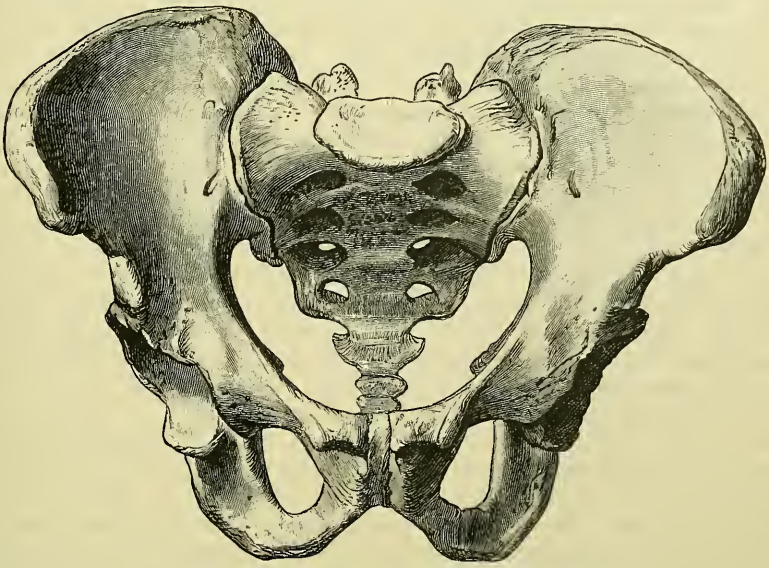


Fig. 166.—Male Pelvis as seen from the Front.

abdominal contents; the part below, the **true pelvis** (pelvis minor) contains the pelvic viscera, and in the female forms the bony canal through which, at full term, the fœtus is expelled.

The **true pelvis** is bounded in front by the symphysis pubis in the middle line, and by the body and rami of the pubis on either side, laterally by the smooth inner surfaces of the ischia and ischial rami, together with a small part of the ilium

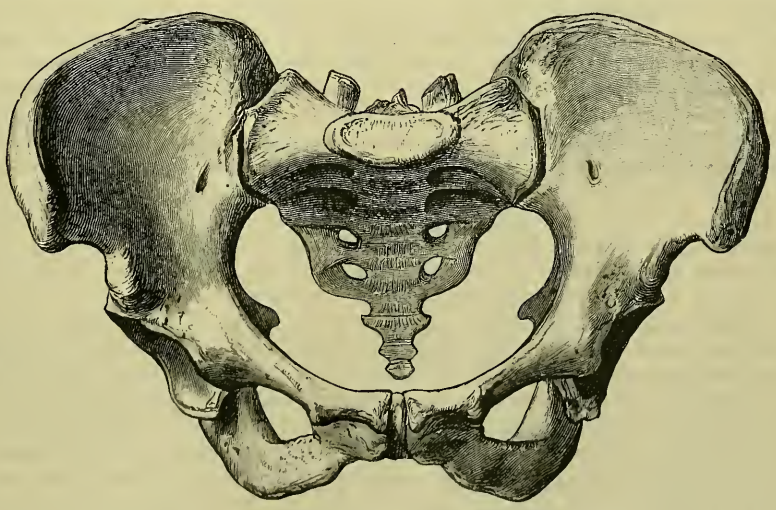


Fig. 167.—Female Pelvis as seen from the Front.

below the iliac portion of the ilio-pectineal line. Springing from the posterior margin of the ischium are the inturned ischial spines. Behind, the broad curved anterior surface of the sacrum, and below it, the small and irregular coccyx, form its posterior wall. Between the sides of the sacrum behind, and the ischium and ilium in front and above, there is a wide interval, called the **sacro-sciatic notch**,

which is, however, bridged across in the recent condition by the great and small sacro-sciatic ligaments, which thus convert it into two foramina, the larger above the spine of the ischium—the great sacro-sciatic foramen, the lower and smaller below the spine, called the small sacro-sciatic foramen.

The **inlet** (apertura pelvis superior) of the pelvis is bounded in front by the symphysis pubis, with the body of the pubis on either side; laterally by the ilio-pectineal lines; and behind by the sacral prominence. The circumference of this aperture is often called the **brim of the pelvis**; in the male its shape is cordate, in the female more oval. The *antero-posterior* or *conjugate diameter* is measured from the sacro-vertebral angle to the symphysis pubis; the *oblique diameter* from the sacro-iliac joint of one side to the ilio-pectineal eminence of the other; whilst the *transverse diameter* is taken across the point of greatest width.

The **outlet** (apertura pelvis inferior) is bounded anteriorly by the **pubic arch** (arcus pubis), formed in front and above by the bodies of the pubis, with the symphysis between them, and the inferior pubic rami below and on either side. These latter are continuous with the ischial rami which pass backwards and outwards to the ischial tuberosities, which are placed on either side of this aperture. In the middle line and behind, the tip of the coccyx projects forward, and in the recent condition the interval between this and the ischial tuberosities is bridged across by the great sacro-sciatic ligament, the inferior edge of which necessarily assists in determining the shape of the outlet.

As the anterior wall of the cavity, formed by the symphysis pubis, measures from $1\frac{1}{2}$ to 2 inches, whilst the posterior wall, made up of the sacrum and coccyx, is from 5 to 6 inches in length, it follows that the planes of the inlet and outlet are not parallel, but placed at an angle to each other. The term **axis of the pelvis** is given to lines drawn at right angles to the centre of these planes. Thus, with the pelvis in its true position, when the figure is erect, the axis of the inlet corresponds to a line drawn downwards and backwards from the umbilicus towards the tip of the coccyx below, whilst the axis of the outlet is directed downwards and slightly backwards, or downwards and a little forwards, varying according to the length of the coccyx. Between these two planes the axis of the cavity, as it passes through planes of varying degrees of obliquity, describes a curve repeating pretty closely the curve of the sacrum and coccyx.

Position of the Pelvis.—The position of the pelvis in the living when the figure is erect may be approximately represented by placing it so that the anterior superior iliac spines and the symphysis pubis lie in the same vertical plane. Under these conditions the plane of the inlet is oblique, and forms with a horizontal line an angle of from 50° to 60°. The position of the pelvis depends upon the length of the ilio-femoral ligaments of the hip-joint, being more oblique when these are short, as usually happens in women in whom the anterior superior iliac spines tend to lie in a plane slightly in advance of that occupied by the symphysis pubis. In cases where the ilio-femoral ligament is long, a greater amount of extension of the hip-joint is permitted, and this leads to a lessening of the obliquity of the pelvis. This condition, which is more typical of men, results in the anterior superior iliac spines lying in a plane slightly posterior to the plane of the symphysis, whilst the angle formed by the plane of the inlet and the horizontal is thereby reduced. Bearing in mind the oblique position of the pelvis, it will now be seen that the front of the sacrum is directed downwards more than forwards, and that the sacral promontory is raised as much as from $3\frac{1}{2}$ to 4 inches above the upper border of the symphysis pubis, lying higher than the level of a line connecting the two anterior superior iliac spines. From the manner in which the sacrum articulates with the ilia, it will be noticed that the weight of the trunk is transmitted downwards through the thickest and strongest part of the bone (see Architecture) to the upper part of the acetabula, where these rest on the heads of the femora.

Sexual Differences.—The female pelvis is lighter in its construction than that of the male; its surfaces are smoother, and the indications of muscular attachments less marked. Its height is less and the splay of its walls not so pronounced as in the male, so that the female pelvis has been well described as a short segment of a long cone as contrasted with the male pelvis, which is a long segment of a short cone. The cavity of the true pelvis in the female is more roomy, and the ischial spines not so much inturned. The pubic arch is wide and rounded, and will usually admit a right-angled-set square

being placed within, so that the summit touches the under surface of the symphysis pubis, whilst the sides lie in contact with the ischial rami. In the male the arch is narrow and angular, forming an angle of from 65° to 70°. The sacro-sciatic notch in the female is wide and shallow. The distance from the posterior edge of the body of the ischium to the posterior inferior iliac spine is longer, measuring on an average 50 mm. (2 inches) in the female, as contrasted with 40 mm. ($1\frac{5}{8}$ inches) in the male.

The inlet in the female is large and oval or reniform, as compared with the cribbed and heart-shaped aperture in the male. The sacro-vertebral angle is more pronounced in the female, and the obliquity of the inlet greater. The sacrum is shorter and wider. The posterior superior iliac spines lie wider apart; the pubic crests are longer; and the pubic spines are separated by a greater interval than in man. The outlet is larger; the tuberosities of the ischia are farther apart; and the coccyx does not project forward so much. The curve of the sacrum is liable to very great individual variation. As a rule the curve is more uniform in the male, whilst in the female it tends to be flatter above and more accentuated below. There is a greater proportionate width between the acetabular hollows in the female than in the male. Of much importance from the standpoint of the obstetrician are the various diameters of the true pelvis. In regard to this it is worthy of note that the plane of "greatest pelvic expansion" extends from the union between the second and third sacral vertebræ behind, to the middle of the symphysis pubis in front, its lateral boundaries on either side corresponding with the mid-point of the inner surface of the acetabulum; whilst the plane of "least pelvic diameter" lies somewhat lower, and is defined by lines passing through the sacro-coccygeal articulation, the ischial spines, and the lower third of the symphysis pubis (Norris). Subjoined is a table showing the principal average measurements in the two sexes:—

	Males.	Females.
Maximum distance between the iliac crests	$11\frac{1}{8}$ in., or 282 mm.	$10\frac{3}{4}$ in., or 273 mm.
Distance between the anterior superior iliac spines	$9\frac{1}{2}$ in., or 240 mm.	$9\frac{3}{4}$ in., or 250 mm.
Distance between the last lumbar spine and the front of the symphysis pubis	7 in., or 176 mm.	$7\frac{1}{8}$ in., or 180 mm.

TRUE PELVIS.

	Males.		Females.			
				Cavity.		
	Inlet.	Outlet.	Inlet.	Greatest.	Least.	Outlet.
Antero-posterior (conjugate) diameter	4 in., or 101 mm.	$3\frac{3}{4}$ in., or 95 mm.	$4\frac{3}{8}$ in., or 110 mm.	5 in., or 127 mm.	$4\frac{3}{8}$ in., or 110 mm.	$4\frac{1}{2}$ in., or 115 mm.
Oblique diameter	$4\frac{3}{4}$ in., or 120 mm.	$3\frac{1}{2}$ in., or 88 mm.	5 in., or 125 mm.	...	...	$4\frac{1}{2}$ in., or 115 mm.
Transverse diameter	5 in., or 127 mm.	$3\frac{1}{2}$ in., or 88 mm.	$5\frac{1}{4}$ in., or 135 mm.	$4\frac{7}{8}$ in., or 125 mm.	$4\frac{3}{8}$ in., or 110 mm.	$4\frac{3}{8}$ in., or 110 mm.

Growth of the Pelvis.—From the close association of the pelvic girdle with the lower limb we find that its growth takes place concurrently with the development of that member. At birth the lower limbs measure but a fourth of the entire body length; consequently at that time the pelvis, as compared with the head and trunk, is relatively small. At this period of life the bladder in both sexes is in greater part an abdominal organ, whilst in the female the uterus has not yet sunk into the true pelvic cavity, and the ovaries and Fallopian tubes rest in the iliac fossæ. The sacro-vertebral angle, though readily recognised, is as yet but faintly marked. Coincident with the remarkable growth of the lower limbs and the assumption of the erect position when the child begins to walk, striking changes take place in the form and size of the pelvis. These consist in a greater expansion of the iliac bones necessarily associated with the growth of the muscles which control the movements of the hip, together with a marked increase in the sacro-vertebral angle due to the development of a forward lumbar curve; at the same time, the weight of the trunk being thrown on the sacrum causes the elements of that bone to sink to a lower level between the innominate bones. The cavity of the true pelvis increases in size proportionally, and the viscera afore-mentioned now begin to sink down and have assumed a position within the pelvis by the fifth or sixth year. The extension of the thighs in the

upright position necessarily brings about a more pronounced pelvic obliquity, whilst the stoutness and thickness of the ilium over the upper part of the acetabulum is much increased to withstand the pressure to which it is obviously subjected. Coincident with this is the gradual development of the iliac portion of the ilio-pectineal line, which serves in the adult to separate sharply the false from the true pelvis. This part of the bone is remarkably strong, as has been shown (see Architecture), and serves to transmit the body weight from the sacrum to the thigh bone. The sexual differences of the pelvis, so far as they refer to the general configuration of this part of the skeleton, are as pronounced at the third or fourth month of fœtal life as they are in the adult (Fehling, *Ztschr. f. Geburtsh. u. Gynaek.* Bd. ix. and x.; A. Thomson, *Journ. Anat. and Physiol.* vol. xxxiii. p. 359). The rougher appearance of the male type is correlated with the more powerful muscular development.

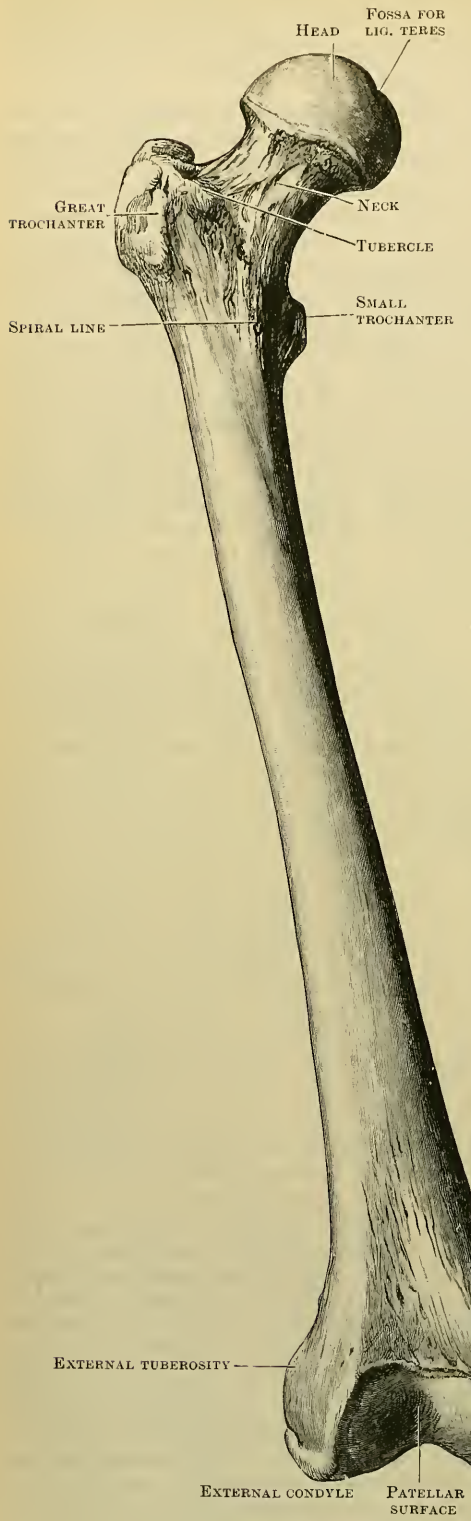


Fig. 168.—Right Femur as seen from the Front.

The Femur.

The **femur** or thigh bone is remarkable for its length, being the longest bone in the body. Superiorly the femora are separated by the width of the pelvis. Inferiorly they articulate with the tibiæ and patellæ. In the military position of attention, with the knees close together, the shafts of the thigh bones occupy an oblique position. For descriptive purposes the bone is divided into an upper extremity, comprising the **head**, **neck**, and two **trochanters**; a **shaft**; and a **lower extremity**, forming the expansions known as the **condyles**.

The **head** (caput femoris) is the hemispherical articular surface which, when coated with cartilage, fits into the acetabular hollow. Its pole is directed upwards and inwards and slightly forwards. A little below the summit, and usually somewhat behind it, is a hollow oval pit (fovea capitis femoris) for the attachment of the ligamentum teres. The circumference of the head forms a lip with a wavy outline, more prominent above and behind than in front. The head is supported by a stout compressed bar of bone, the **neck** (collum femoris), which forms with the upper end of the shaft an angle of about 125 degrees, and is directed upwards, inwards, and a little forwards. Its vertical width exceeds its antero-posterior thickness. Constricted about its middle, it expands internally to support the head, whilst externally, where it joins the shaft, its vertical diameter is

much increased. Anteriorly it is clearly defined from the shaft by a rough ridge which commences above on a prominence, sometimes called the **tubercle** of the femur, and passes obliquely downwards and inwards. This constitutes the upper part of the **spiral line** (linea inter-trochanterica), and serves for the attachment of the ilio-femoral ligament of the hip-joint. Posteriorly where the neck unites with the shaft, there is a full rounded ridge passing from the trochanter major above to the trochanter minor below; this is the posterior **intertrochanteric line** or **ridge** (crista intertrochanterica). A little above the middle of this ridge there is usually a fulness which serves to indicate the upper limit of attachment of the quadratus femoris muscle, and is called the **tubercle for the quadratus.** Externally the neck is embedded in the inner surface of the trochanter major, by which, at its upper and back part, it is to some extent overhung. Here is situated the **digital fossa** (fossa trochanterica), into which the tendon of the obturator externus is inserted. Passing nearly horizontally across the back of the neck there is a faint groove leading into this depression; in this the tendon of the obturator externus muscle lies. Inferiorly the neck becomes confluent with the trochanter minor behind, and is continuous with the inner surface of the shaft in front. The neck is pierced by many vascular canals, most numerous at the upper and back part. Some are directed upwards towards the head, whilst others pass in the direction of the trochanter major.

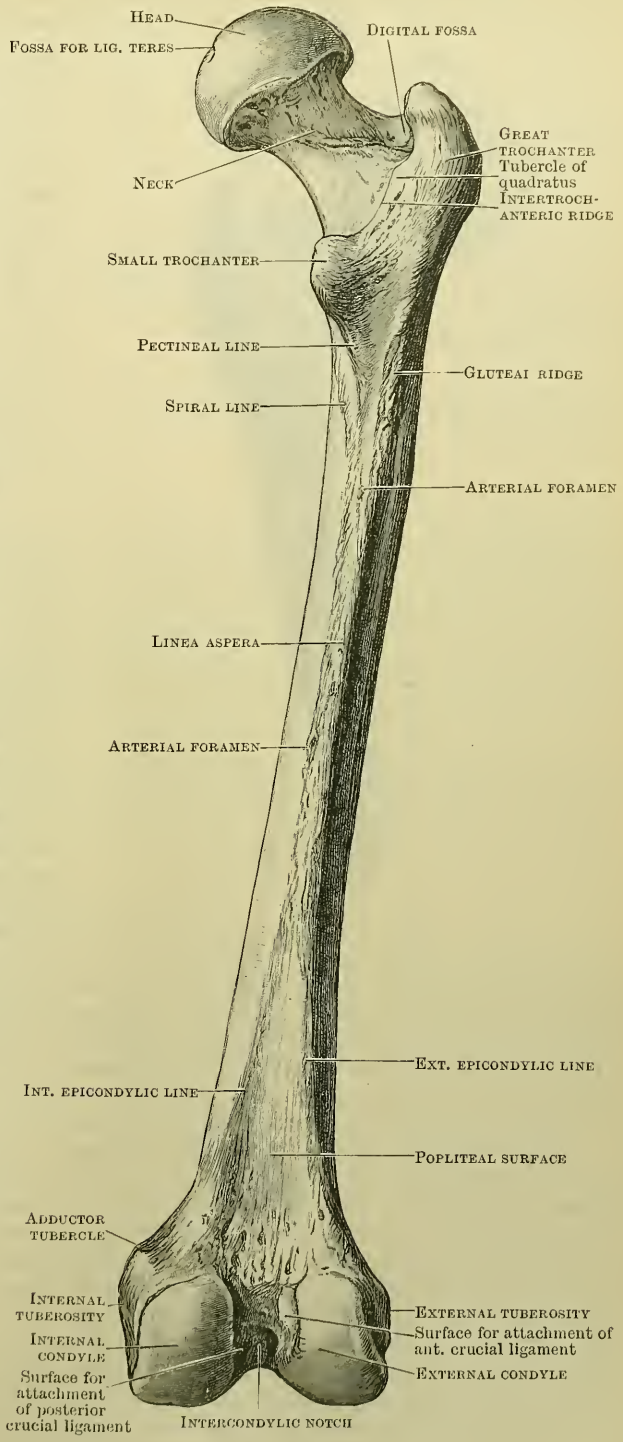


Fig. 169.—Right Femur as seen from Behind.

The **trochanter major** is a large quadrangular process which caps the upper and outer part of the shaft, and overhangs the root of the neck above and behind. Its *outer surface*, of rounded irregular form, slopes upwards

and inwards, and is separated from the external surface of the shaft below by a more or less horizontal ridge. Crossing it obliquely from the posterior superior to the anterior inferior angle is a rough line which serves for the insertion of the gluteus medius muscle; above and below this the surface of the bone is smoother and is overlain by bursæ. The *anterior surface*, somewhat oblong in shape, and inclined obliquely from below upwards and inwards, is elevated from the general aspect of the shaft below, from which it is separated in front by an oblique line leading upwards and inwards to the tubercle at the upper end of the superior part of the spiral line. This surface serves for the insertion of the gluteus minimus. The *superior border* is curved and elevated; into it are inserted the tendons of the obturator internus and gemelli muscles within and in front, and the pyriformis muscle above and behind. The *posterior border* is thick and rounded, and forms the upper part of the posterior intertrochanteric ridge. The angle formed by the superior and posterior borders is sharp and pointed, and forms the tip of the trochanter overhanging the digital fossa, which lies immediately below and within its inner surface.

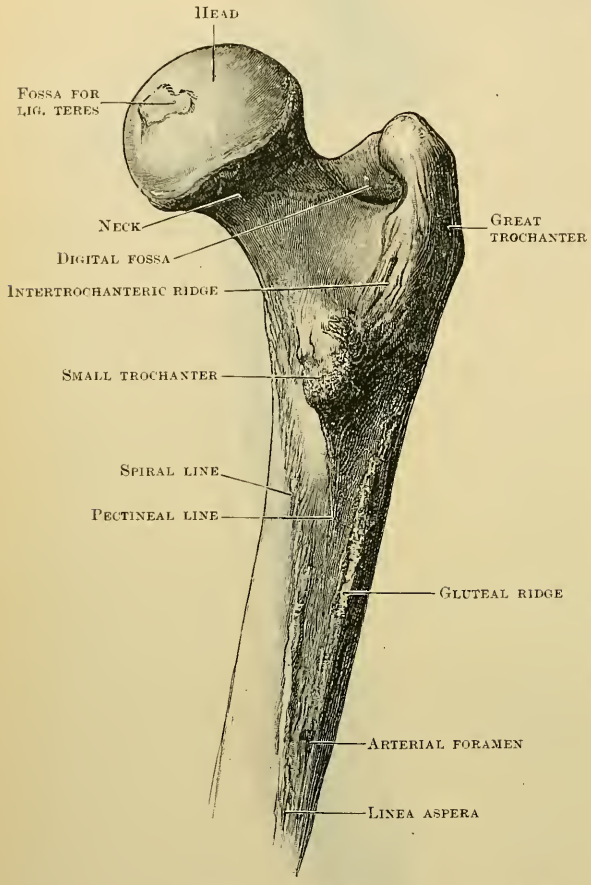


Fig. 170.—Back View of Upper End of Right Femur.

The **trochanter minor** is an elevated pyramidal process situated at the back of the inner and upper part of the shaft where that becomes continuous with the lower and posterior part of the neck. Confluent above with the posterior intertrochanteric ridge, it gradually fades away into the back of the shaft below. The combined tendon of the ilio-psoas is inserted into this process and the bone immediately below it.

The **shaft** (corpus femoris), which is characterised by its great length, is cylindrical in form. As viewed from the front, it is straight or but slightly curved; as seen in profile, it is bent forwards, the curve being most pronounced in its upper part. The shaft is thinnest at some little distance above its middle; below this it gradually increases in width to support the condyles inferiorly; its antero-posterior diameter, however, is not much increased below. Its surfaces are generally smooth and rounded, except behind, where, running longitudinally down the centre of its curved posterior aspect, there is a rough-lipped ridge, the **linea aspera** (linea aspera). Most salient towards the middle of the shaft, the linea aspera consists of an inner lip (labium mediale) and an outer lip (labium laterale), with a narrow intervening rough surface. Above, about 2 to $2\frac{1}{2}$ inches from the trochanter minor, the linea aspera is formed by the convergence of three lines. Of these the outer is a rough, somewhat elevated, ridge, which commences above, on the back of the shaft, external to and on a level with the trochanter minor, and becomes continuous below with the outer lip of the linea aspera. This serves for the bony insertion of the gluteus maximus, and is occasionally developed into an outstanding process called the **trochanter tertius.** Internally the inner lip of the linea aspera is confluent above with a line which winds round the shaft upwards and forwards in front of the

trochanter minor to become continuous with the rough ridge which serves to define the neck from the shaft anteriorly (see *ante*). The whole constitutes what is known as the **spiral line**, and extends from the fore and upper part of the trochanter major above to the linea aspera below. Intermediate in position between the spiral line in front and internally, and the gluteal ridge externally, there is a third line, the **pectineal line** (linea pectinea), which passes down from the trochanter minor and fades away inferiorly into the surface between the two lips of the linea aspera. Into this the pectineus muscle is inserted. About the junction of the middle with the lower third of the shaft the two lips of the linea aspera separate from one another, each passing in the direction of the condyle of the corresponding side. The lines so formed are called the inner and outer epicondylic lines respectively, and enclose between them a smooth triangular area corresponding to the back of the lower third of the shaft; this, called the **popliteal surface** (planum popliteum), forms the floor of the upper part of the popliteal space. The continuity of the upper part of the internal epicondylic line is but faintly marked, being interrupted by a wide and faint groove along which the popliteal artery passes to enter the space of that name. Below, where the line ends on the upper and inner surface of the internal condyle, there is a little spur of bone called the **adductor tubercle**, to which the tendon of the adductor magnus is attached, and behind which the inner head of the gastrocnemius muscle takes origin.

The **linea aspera** affords extensive linear attachments to many of the muscles of the thigh. The vastus internus arises from the spiral line above and the inner lip of the linea aspera below. The adductor longus is inserted into the inner lip about the middle third of the length of the shaft. The adductor magnus is inserted into the intermediate part of the line, extending as high as the level of the trochanter minor, where it lies internal to the insertion of the gluteus maximus. Below, its insertion passes on the internal epicondylic ridge, reaching as low as the adductor tubercle. The adductor brevis muscle is inserted into the linea aspera above, between the pectineus and adductor longus muscles internally and the adductor magnus externally. Below the insertion of the gluteus maximus the short head of the biceps arises from the outer lip as well as from the external epicondylic line; in front these also serve for the origin of the vastus externus muscle.

The canals for the nutrient arteries of the shaft, which have an upward direction, are usually two in number, and are placed on or near the linea aspera—the upper one about the level of the junction of the middle and upper third of the bone, the lower some three or four inches below—usually on the inner side of the shaft, immediately in front of the inner lip of the linea aspera.

The front and lateral aspects of the shaft are covered by, and furnish surfaces for, the origins of the vasti and crureus muscles.

The **lower extremity** of the femur comprises the two **condyles**. These are two recurved processes of bone, each provided with an articular surface, and separated behind by a deep **intercondylic notch**. United in front, where their combined articular surfaces form an area on which the patella rests, the two condyles differ from each other in the following respects: If the shaft of the bone be held vertically, the **internal condyle** is seen to reach a lower level than the **external**; but, as the femur lies obliquely in the thigh, the condyles are so placed that their inferior surfaces lie in the same horizontal plane. Viewed from below, the internal condyle is seen to be the narrower and shorter of the two. The external condyle is broader, and advances farther forward and higher up on the anterior surface of the shaft. The **intercondylic notch** (fossa intercondyloidea) reaches forwards as far as a transverse line drawn through the centre of the external condyle. Its sides are formed by the inner and outer surfaces of the outer and inner condyles respectively, the latter being more deeply excavated, and displaying an oval surface near its lower and anterior part for the attachment of the posterior crucial ligament of the knee-joint. Placed high up, on the posterior part of the inner surface of the external condyle, there is a corresponding surface for the attachment of the anterior crucial ligament. The floor of the notch, which is pierced by numerous vascular canals, slopes upwards and backwards towards the popliteal surface on the back of the shaft, from which it is separated by a slight ridge (linea intercondyloidea) to which the posterior part of the capsule of the knee-joint is attached.

The cutaneous aspect of each condyle (*i.e.* the outer surface of the external condyle and the inner surface of the internal condyle) presents an elevated rough

surface, called the **tuberosity** (epicondylus), that of the **internal** (epicondylus medialis) being the more pronounced and outstanding from the line of the shaft; capped above by the adductor tubercle, it affords attachment near its most prominent point to the fibres of the internal lateral ligament of the knee-joint. The **external tuberosity** (epicondylus lateralis), less pronounced and lying more in line with the outer surface of the shaft, is channelled behind by a curved groove, the lower rounded lip of which serves to separate it from the inferior articular surface. This groove ends in front in a pit which is placed just below the most salient point of the tuberosity; hereto is attached the tendon of the popliteus muscle, which overlies the lower lip of the groove in the extended position of the joint, but slips into and occupies the groove when the joint is flexed. Behind the most prominent part of the external tuberosity, and just above the pit for the attachment of the popliteus, the external lateral ligament of the knee-joint is attached, whilst superior to that there is a circumscribed area for the origin of the tendinous part of the outer head of the gastrocnemius muscle.

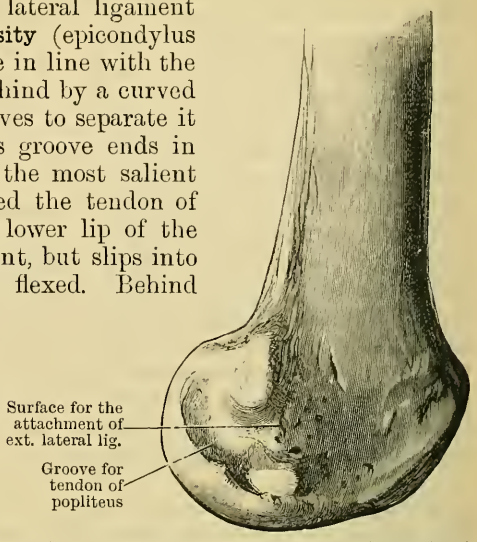


Fig. 171.—Lower End of Right Femur (Outer Side).

The **articular surface** on the lower extremity is divisible into three parts—that which corresponds to the inferior surface of the shaft and which is formed by the coalescence of the two condyles in front, and those which overlie the under and hinder aspects of each of those processes. The former is separated from the latter by two shallow oblique grooves which traverse the articular surface from before backwards, on either side, in the direction of the anterior part of the intercondylic notch. These furrows are the impressions in which fit the fore-parts of the internal and external semilunar cartilages of the knee-joint respectively, when the knee-joint is extended. The anterior articular area or **trochlea** (facies patellaris) is adapted for articulation with the patella. Convex from above downwards, it displays a broad and shallow central groove, bounded on either side by two slightly convex surfaces. Of the two sides, the external is the wider and more prominent, and rises on the front of the bone to a higher level than the internal. The **condyloid or tibial surfaces** are convex from side to side, and convex from before backwards. Sweeping round the under surface and posterior extremities of the condyles, they describe a spiral curve more open in front than behind. The inner condyloid articular surface is narrower than the outer, and when viewed from below is also seen to describe a curve around a vertical axis. The articular surface of the external condyle is inclined obliquely from before backwards and slightly outwards. The surfaces of the condyles above the articular area posteriorly are confluent superiorly with the popliteal surface of the shaft; from these areas the heads of the gastrocnemius muscles arise. The bone from which the inner head of the muscle springs is often elevated in the form of a tubercle placed on the lower part of the popliteal surface of the shaft, just above the internal condyle. The proportionate length of the femur to the body height is as 1 is to 3·53–3·92.

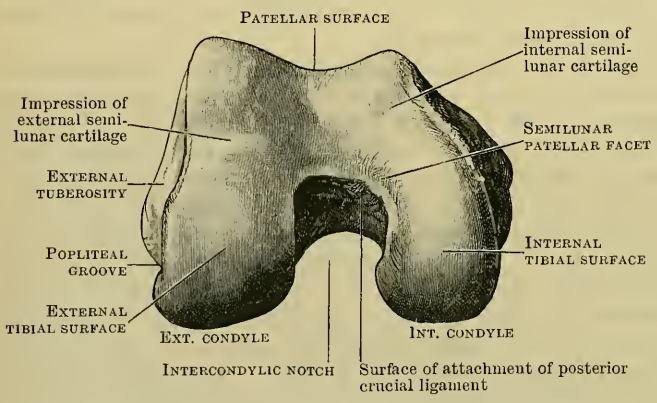


Fig. 172.—Lower End of Right Femur as seen from Below.

Arterial Foramina.—Numerous vascular canals are seen in the region of the neck, at the bottom of the digital fossa, on the posterior intercondylic ridge and on the external surface of the great trochanter. The nutrient arteries for the shaft pierce the bone on or near the linea aspera. Both back and front of the lower end of the shaft display the openings of numerous vascular canals, and the floor of the intercondylic notch is also similarly pierced.

Connexions.—The femur articulates with the os innominatum above and the tibia and patella below. The external surface of the great trochanter determines the point of greatest hip width in the male, being covered only by the skin and superficial fascia and the aponeurotic insertion of the gluteus maximus. In the erect position the tip of the trochanter corresponds to the level of the centre of the hip-joint. When the thigh is flexed the trochanter major sinks under cover of the anterior fibres of the gluteus maximus. In women the hip width is usually greatest at some little distance below the trochanter, due to the accumulation of fat in this region. The shaft of the bone is surrounded on all sides by muscles. Its forward curve, however, is accountable to some extent for the fulness of the front of the thigh. The exposed surfaces of the condyles determine to a large extent the form of the knee. In flexion the articular edges can easily be recognised on either side of and below the patella.

Architecture.—The shaft has a medullary cavity which reaches as high as the root of the small trochanter. Inferiorly it extends to within $3\frac{1}{2}$ inches of the lower articular surface. In the upper half the outer compact wall is very thick, but below the middle of the shaft it gradually thins until it reaches the condyles inferiorly, over which it passes as a thin, hardly definable external layer. Above, it is especially thick along the line of the linea aspera, and here the large nutrient canal may be seen passing obliquely upwards in the substance of the dense bone for the space of two inches. In the upper end of the shaft the osseous lamellæ springing from the sides of the medullary cavity arch inwards towards the centre, intersecting each other in a manner comparable to the tracery of a Gothic window. The lower wall of the neck is thick below, near the trochanter minor, but thins rapidly before it reaches the head. From this aspect of the neck there spring a series of oblique lamellæ which pass upwards and inwards, spreading in fan-shaped manner into the under surface of the head. These are intersected above by lamellæ which arch inwards from the outer side of the shaft below the great trochanter, as well as from the under surface of the thin but compact outer shell of the upper surface of the neck, the whole forming a bracket-like arrangement which assists materially in adding to the strength of the neck. Further support is given by the addition of a spur of dense bone which springs from the inner surface of the under side of the neck, just in front of and above the trochanter minor: this is called the **calcar femorale**. From it stout lamellæ having a vertical direction arise. The spongy tissue of the head and great trochanter is finely reticulated, that of the lower part of the neck and upper part of the shaft being more open in its texture. Passing vertically downwards through this tissue there is a vascular canal, the orifice of which opens externally on the floor of the digital fossa.

The spongy tissue of the lower part of the shaft is more delicate and uniform in its arrangement, displaying a more or less parallel striation in a longitudinal direction. Subjacent to the articular surface the tissue is rendered more compact by the addition of lamellæ disposed in curves in harmony with the external aspect of the bone.

Variations.—Absence of the pit on the head of the femur for the attachment of the ligamentum teres has been recorded. This corresponds with the condition met with in the orang. Not infrequently there is an extension of the articular surface of the head on to the fore and upper aspect of the neck; this is a "pressure facet" caused by the contact of the iliac portion of the acetabular margin with the neck of the bone, when the limb is maintained for long periods in the flexed position, as in tailors, and also in those races who habitually squat (Lane, *Journ. Anat. and Physiol.*, vol. xxii. p. 606).

The occurrence of a trochanter tertius has been already referred to. Its presence is not confined to individuals of powerful physique, but may occur in those of slender build, so far suggesting that it is not to be regarded merely as an indication of excessive muscular development. The observations of Dixon (*Journ. Anat. and Physiol.*, vol. xxx. p. 502), who noted the occurrence of a separate epiphysis in three cases in connexion with it, seem to point to its possessing some morphological significance.

Occasionally the gluteal ridge may be replaced by a hollow, the fossa hypotrochanterica, or in some cases the two may co-exist.

The angle of the neck is more open in the child than in the adult, and tends to be less when the femoral length is short and the pelvic width great—conditions which particularly appertain to the female. There is no evidence to show that after growth is completed any alteration takes place in the angle with advancing years (Humphry).

The curvature of the shaft may undergo considerable variations, and the appearance of the posterior surface of the bone may be modified by an absence of the linea aspera, a condition resembling that seen in apes; or by an unusual elevation of the bone which supports the ridge (*fémur à pilastre*), produced, as Manouvrier has suggested, by the excessive development of the muscles here attached.

Under the term "*platymerie*," Manouvrier describes an antero-posterior compression of the upper part of the shaft, frequently met with in the femora of prehistoric races.

Ossification.—The shaft begins to ossify early in the second month of fœtal life, and at birth displays enlargements at both ends, which are capped with cartilage. If the inferior cartilaginous end be sliced away, a small ossific nucleus for the inferior epiphysis will usually be seen. This, as a rule, makes its appearance towards the latter end of the ninth month

of fœtal life, and is at service from a medico-legal standpoint in determining the age of the fœtus. According to Hartman, it is absent in about 12 per cent of children at term, and may appear as early as the eighth month of fœtal life in about 7 per cent. The superior extremity, entirely cartilaginous at birth, comprises the head, neck, and trochanter major. A centre appears for the head during the early part of the first year. That for the trochanter major begins to ossify about the second or third year, whilst the neck is developed as an upward extension of the shaft, which is, however, not confined to the neck alone, but forms the lower circumference of the articular head, as may be seen in bones up to the age of twelve or sixteen; after that, the separate epiphysis of the head begins to overlap it so as to cover it entirely when fusion is complete at the age of eighteen or twenty.

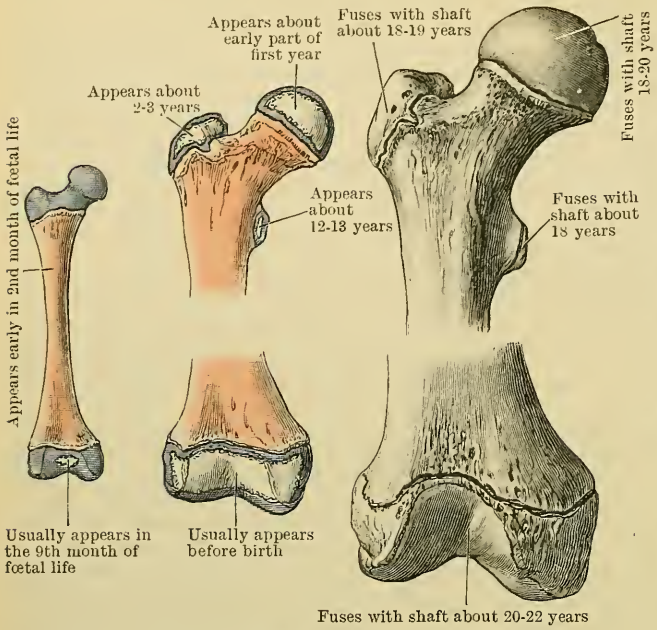


Fig. 173.—Ossification of Femur.

The epiphysis of the great trochanter unites with the shaft and neck about eighteen or nineteen, whilst the epiphysis for the trochanter minor, which usually makes its appearance about the twelfth or thirteenth year, is usually completely fused with the shaft about the age of eighteen. The epiphysis for the lower end, although the first to ossify, is not completely united to the shaft until from about the twentieth to the twenty-second year. It is worthy of note that the line of fusion of the shaft and inferior epiphysis passes through the adductor tubercle, a point which can easily be determined in the living.

The Patella.

The **patella**, the largest of the sesamoid bones, overlies the front of the knee-joint in the tendon of the quadriceps extensor. Of compressed form and somewhat triangular shape, its lower angle projects downwards and forms a peak, called the **apex** (apex patellæ), whilst its upper edge, or **base** (basis patellæ), broad, thick, and sloping forwards and a little downwards, is divided into two areas by a transverse line or groove; the anterior area so defined serves for the attachment of the common tendon of the quadriceps extensor muscle, whilst the posterior, of compressed triangular shape, is covered by synovial membrane. The *inner* and *outer borders*, of curved outline, receive the insertions of the vastus internus and externus muscles respectively, the

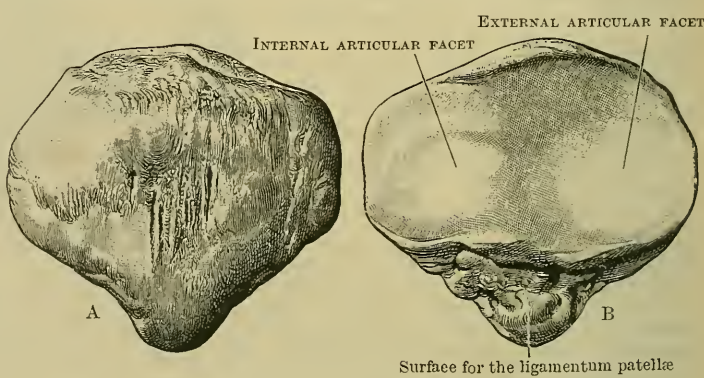


Fig. 174.—Right Patella.

A. Anterior surface. B. Posterior surface.

attachment of the vastus internus being more extensive than that of the vastus externus. The *anterior surface* of the bone, slightly convex in both diameters, has a fibrous appearance, due to its longitudinal striation, and is pierced here and there by the openings of vascular canals. The *posterior* or *femoral articular surface* is divided into two unequal parts (of which the external is the wider) by a vertical elevation which glides in the furrow of the trochlear surface of the femur, and in extreme flexion passes to occupy the intercondylic notch. The outer of the two femoral surfaces is slightly concave in both its diameters; the inner, though slightly concave from above downwards, is usually plane, or somewhat convex transversely. Occasionally, in the macerated bone, indications of a third vertical area are to be noted along the inner edge of the internal aspect. This defines the part of the articular surface which rests on the border of the internal condyle in extreme flexion.

Below the femoral articular area the deep surface of the apex is rough and irregular; the greater part of this is covered by synovial membrane, the ligamentum patellæ being attached to its summit and margins, reaching some little distance round the borders on to the anterior aspect of this part of the bone.

Architecture.—The bone consists of a thick dense layer anteriorly, which thins towards the edges on either side and below; above, it corresponds to the area of insertion of the quadriceps. The femoral articular surface is composed of a layer of compact bone, thickest in correspondence with the vertical elevation. Sandwiched between these two layers is a varying thickness of spongy tissue of fairly close grain, the striation of which on cross section runs in parallel lines from back to front; on vertical section the tissue appears to be arranged in lines passing radially from the deep surface of the femoral area to the more extensive anterior dense plate.

Variations.—Cases of congenital absence of the patella have been recorded.

F. C. Kempson (*Journ. Anat. and Physiol.*, vol. xxxvi.) has recently drawn attention to the condition described as emargination of the patella. In specimens displaying this appearance the margin of the bones is concave from a point about half an inch to the outer side of the middle line, to a point half-way down the outer margin of the bone, here there is usually a pointed spine directed upwards and outwards. The condition appears to be associated with the insertion of the tendon of the vastus externus. G. Joachimstal (*Archiv u. Atlas der normalen und pathologischen Anatomie in typischen Röntgenbildern*, Bd. 8) figures a case in which on both sides the patella was double in an adult, the lower and much the smaller portion was embedded in the ligamentum patellæ.

Ossification.—The patella is laid down in cartilage about the third month of fœtal life. At birth it is cartilaginous, and the tendon of the quadriceps is continuous with the ligamentum patellæ over its anterior surface, and can easily be dissected off. About the third year an ossific centre appears in it and spreads more particularly over its deeper surface. Ossification is usually completed by the age of puberty.

The Tibia

The **tibia** is the inner bone of the leg. It is much stouter and stronger than its neighbour the fibula, with which it is united above and below. By its superior expanded extremity it supports the condyles of the femur, while inferiorly it shares in the formation of the ankle-joint, articulating with the upper surface and inner side of the astragalus.

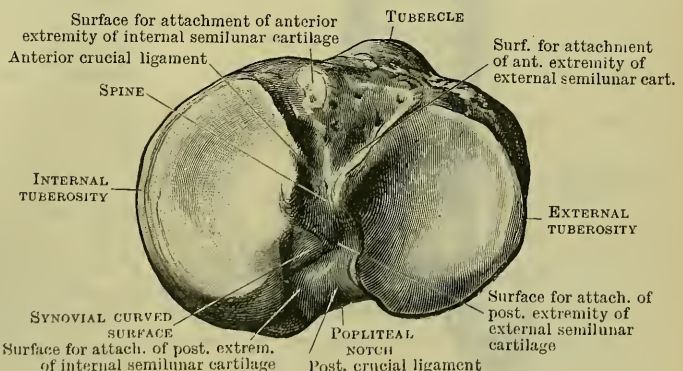


Fig. 175.—Upper Surface of Superior Extremity of Right Tibia.

The **superior extremity** comprises the **inner** and **outer tuberosities**, the **spine**, and the **tubercle**. Each tuberosity is provided on its upper aspect with an articular surface (facies articularis superior), which supports the corresponding femoral condyle, as well as the

interposed semilunar cartilage. Of these two condylic surfaces the **inner** is the larger; of oval shape, its long axis is placed antero-posteriorly. Slightly concave from before backwards and from side to side, its circumference rises in the form of a sharp and well-defined edge. The **outer condylic surface** is smaller and rounder. Slightly concave from side to side, and gently convex from before backwards, its circumference is well defined in front, but is rounded off behind, thus markedly increasing the convexity of its posterior part. Between the two condylic surfaces the bone is raised in the centre to form the **spine** (eminentia intercondyloidea), the summit of which is grooved and capped on either side by **tubercles** which spring from and are formed by the upward extension of the neighbouring condylic areas. Of these tubercles the *inner* (tuberculum intercondyloideum mediale) is the higher, and longer in an antero-posterior direction, the *outer* (tuberculum intercondyloideum laterale) being more pointed and not so elevated. In front and behind the spine the articular areas are separated by two irregular V-shaped surfaces, the **intercondylic fossæ**. The **anterior fossa** (fossa intercondyloidea anterior), the larger and wider, furnishes areas for the attachment of the semilunar cartilages on either side, and for the anterior crucial ligament immediately in front of the spine. The floor of this space is pierced by many nutrient foramina. The **posterior intercondylic fossa** (fossa intercondyloidea posterior) is concave from side to side, and slopes downwards and backwards. The external semilunar cartilage is attached near its apex to a surface which rises on to the back of the spine; the internal semilunar cartilage is fixed to a groove which runs along its inner edge, and the posterior crucial ligament derives an attachment from the smooth posterior rounded surface.

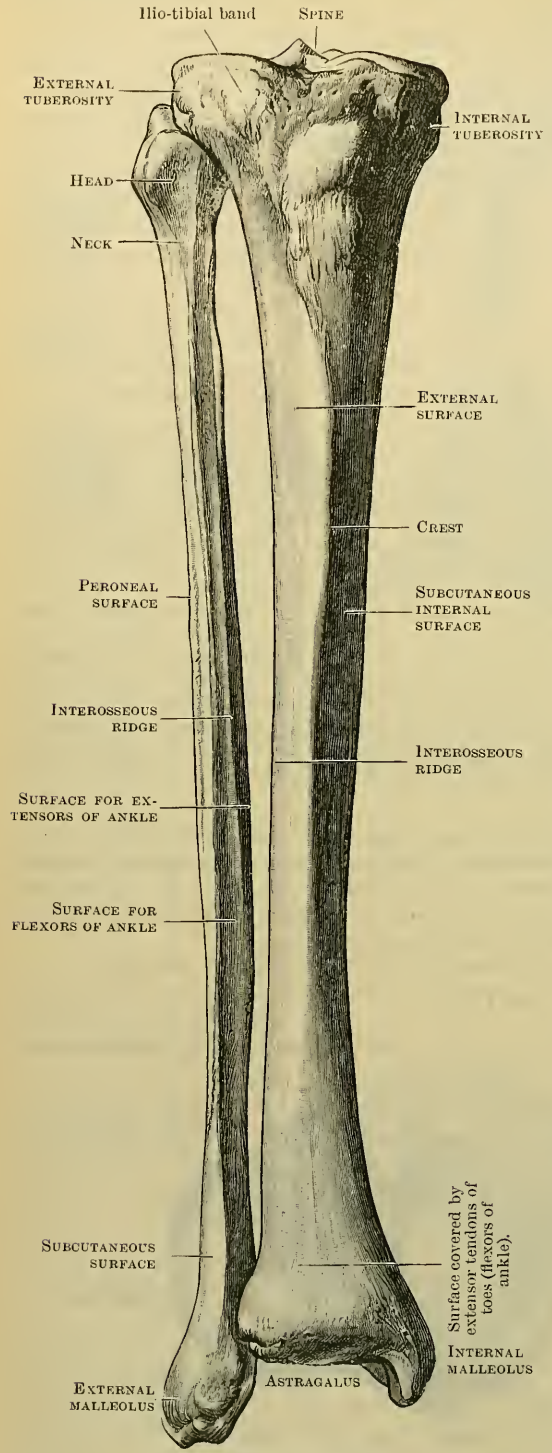


Fig. 176.—Right Tibia and Fibula as seen from the Front.

The **external tuberosity** (condylus lateralis) is the smaller of the two. It overhangs the shaft to a greater extent than the internal, though this is obscured in the living by its articulation with the fibula. The facet for the fibula, often small and indistinct, is placed postero-externally on the under surface of its most projecting part.

Antero-externally the imprint caused by the attachment of the ilio-tibial band is often quite distinct. The circumference of the **internal tuberosity** (condylus medialis) is grooved postero-internally for the insertion of the tendon of the semimembranosus.

In front of the tuberosities, and about an inch below the level of the condylic surfaces, there is an oval elevation called the **tubercle of the tibia**, or the **anterior tuberosity** (tuberositas tibiæ). The upper half of this is smooth and covered by a bursa, while the lower part is rough and serves for the attachment of the ligamentum patellæ.

Considered in its entirety, the upper extremity of the tibia is broader transversely than antero-posteriorly, and is inclined backwards so as to overhang the shaft posteriorly.

The **shaft** (corpus tibiæ) is irregularly three-sided. It is narrowest about the junction of its middle and lower thirds, and expands above and below to support the extremities. Running down the front of the bone there is a gently-curved, prominent margin confluent above with the tubercle, but fading away inferiorly on the anterior surface of the lower third of the bone, where it may be traced in the direction of the anterior border of the internal malleolus. This is the **crest** or **shin** (crista anterior), which is subcutaneous throughout its entire length. To the inner side of this is a smooth, slightly convex surface, which reaches as high as the internal tuberosity above, and inferiorly becomes continuous with the inner surface of the internal malleolus. This is the *internal* or *subcutaneous surface* (facies medialis) of the shaft, which is covered only by skin and superficial fascia, except in its upper fourth, where the tendons of the sartorius, gracilis, and semitendinosus muscles overlie it, as they pass towards their insertions. This surface is limited posteriorly by the **internal border** (margo medialis) which passes from the inner and under surface of the internal tuberosity above to the hinder border of the internal malleolus below. This border is rounded and indefinite above and below, being usually best marked about its middle third. To the outer side of the tibial crest is the *external surface* of the bone (facies lateralis); it is limited behind by a straight vertical ridge, the **crista interossea**, to which the interosseous membrane, which occupies the interval between the tibia and the fibula, is attached. This ridge commences above, near the middle of the outer and under surface of the external tuberosity, and terminates below about two inches above the lower extremity by dividing into two lines, which separate and enclose between them the surface for articulation with the lower end of the fibula, and the area of attachment of the inferior interosseous ligament, which here unites the two bones. In its upper two-thirds the external surface provides an extensive origin for the tibialis anticus. Inferiorly, where the tibial crest is no longer well defined, the external surface turns forward on to the front of the shaft, and is limited inferiorly by the anterior margin of the inferior articular surface. Over this the tendon of the tibialis anticus, and the combined fleshy and tendinous parts of the extensor proprius hallucis and extensor communis digitorum muscles pass obliquely downwards. The *posterior surface* (facies posterior) of the shaft lies between the interosseous ridge externally and the internal border on the inner side. Its contours are liable to considerable variation according to the degree of lateral compression of the bone. It is usually full and rounded above, and flat below. Superiorly it is crossed by the **oblique** or **popliteal line** (linea poplitea), which runs downwards and inwards, from the fibular facet above, to the internal border on a level with the junction of the middle with the upper third of the shaft. To this line, as well as to the internal border for some distance below it, the soleus muscle is attached. Into the bulk of the triangular area above it the popliteus muscle is inserted. Arising from the middle of the popliteal line there is a vertical ridge, which passes downwards and divides the posterior aspect of the shaft into two surfaces—an external for the tibial origin of the tibialis posticus muscle, and an internal for the flexor longus digitorum muscle. The inferior third of this surface of the shaft is free from muscular attachments, but is overlain by the tendons of the above muscles, together with that of the flexor longus hallucis. A large nutrient canal, having a downward direction, opens on the posterior surface of the shaft a little below the popliteal line and just external to the vertical ridge which springs from it.

The **inferior extremity** of the tibia displays an expanded quadrangular form. It is furnished with a saddle-shaped articular surface on its under surface (facies articularis inferior), which is concave from before backwards and slightly convex from side to side. This rests upon the superior articular surface of the body of the astragalus, and is bounded in front and behind by well-defined borders. The anterior border is the rounder and thicker, and is oftentimes channelled by a groove for the attachment of the anterior ligament of the joint; further, it is occasionally provided with a pressure facet caused by the locking of the bone against the neck of the astragalus in extreme flexion. Externally the edge of the articular area corresponds to the base of the triangle formed by the splitting of the interosseous ridge into two parts. Where these two lines join it, both in front and behind, the bone is elevated into the form of tubercles, in the hollow between which (incisura fibularis) the lower end of the fibula is lodged, being held in position by powerful ligaments. The cartilage-covered surface occasionally extends for some little distance above the base of the triangle. Internally there is a down-projecting process, called the **internal malleolus** (malleolus medialis), the inner aspect of which is subcutaneous and forms the projection of the inner ankle. Its external surface is furnished with a pyriform facet (facies articularis malleolaris), confluent above with the cartilage-covered area on the inferior extremity of the shaft; this articulates with a corresponding area on the inner surface of the body of the astragalus. Inferiorly the malleolus is pointed in front, but notched behind for the attachment of the internal lateral ligament of the ankle. Running obliquely along the posterior surface of the malleolus there is a broad groove (sulcus malleolaris) in which the tendons of the tibialis posticus and flexor longus digitorum muscles are lodged; whilst a little to the fibular side of this, and running downwards over the posterior surface of the lower extremity of the bone, there is another groove, often faintly marked, for the lodgment of the tendon of the flexor longus hallucis muscle. The proportionate length of the tibia to the body height is as 1 is to 4·32–4·80.

Arterial Foramina.—Nutrient canals are seen piercing the upper extremity of the bone around its circumference and above the tubercle. The floors of the intercondylic fossæ are also similarly pierced, and there is usually a canal of large size opening on the summit of the spine. Two or three foramina of fair size are seen running upwards into the substance of the bone a little below and to the inner side of the tubercle, while the principal vessel for the shaft passes downwards into the bone on its posterior surface, about the level of the junction of the upper and middle thirds. The inner surface of the internal malleolus, as well as the anterior and posterior borders of the inferior extremity, are likewise pitted by the orifices of small vascular channels.

Connexions.—Superiorly the tibia supports the condyles of the femur, and is connected in front with the patella by means of the patellar ligament. Articulating externally with the fibula above and below, it is united to that bone throughout nearly its entire length by the interosseous membrane. The crest and internal surface can be readily examined, as they are subcutaneous, except above where the internal surface is overlain by the thin tendinous aponeurosis of the muscles passing over the inner side of the knee. The form of the lower part of the knee in front is determined by the tuberosities on either side crossed mesially by the ligamentum patellæ. Inferiorly the internal malleolus forms the projection of the inner ankle, which is wider, not so low, less pointed, and placed in advance of the projection of the outer ankle. The front and back of the lower end of the bone are crossed by tendons, which mask to a certain extent its form.

Architecture.—The shaft of the bone is remarkable for the thickness and density of the osseous tissue which underlies the crest. The posterior wall is stout, but the internal and external walls are thinner. The several walls are thickest opposite the middle of the shaft, and thin out above and below where the shaft unites with the epiphyses. The medullary canal, narrow and circular in the middle of the bone, increases in all its diameters above and below, and reaches to within 2½ to 3 inches of either extremity. Superiorly the arrangement of the lamellæ of the spongy tissue resembles a series of arches springing from the dense outer walls. These form a platform on which the superior epiphysis rests, the spongy tissue of which displays a more or less vertical striation. This is much more compact under the condylic surfaces, the superficial aspect of which is formed by a thin layer of dense bone. The spine and tubercle are also formed of compact tissue, whilst the circumference of the tuberosities is covered by a thinner and less dense wall. In the lower end of the shaft the spongy tissue, of a loose and cellular character, is arranged in vertical fibres, blending inferiorly with the closer tissue of the inferior epiphysis, the articular surface of which is covered by a thin but dense layer.

In the adult bone the nutrient canal for the shaft is embedded in the dense posterior wall for the space of two inches.

Variations —The tibia is often unduly laterally compressed, leading to an increase in its

antero-posterior diameter as compared with its transverse width. This condition is more commonly met with in the bones of prehistoric and savage races than in modern Europeans. Attention was first directed to this particular form by Busk, who named the condition **platycnemia**. The general appearance of such tibiæ resembles that seen in the apes, and depends on an exceptional development of the tibialis posticus muscle, though, as Manouvrier has pointed out, in apes this is associated with the direct action of the muscle on the foot, as in climbing, whereas in man, as a consequence of the bipedal mode of progression, the muscle is employed in an inverse sense, viz. by steadying the tibia on the foot, and thus providing a fixed base on which the femur can move. Such platycnemic tibiæ are occasionally met with in the more highly civilised races, and are, according to Manouvrier, associated with habits of great activity among the inhabitants of rough and mountainous districts.

Another interesting condition is one in which the upper extremity is more strongly recurved than is usual. This retroversion of the head of the tibia was at one time supposed to represent an intermediate condition in which the knee could not be fully extended so as to bring the axis of the leg in line with the thigh; but such opinion has now been upset by the researches of Manouvrier, who claims that it is the outcome of a habit not uncommon amongst peasants and countrymen, viz. that of walking habitually with the knees slightly bent.

Habitual posture also leaves its impress on the form of the tibia, and in races in which the use of the chair is unknown, the extreme degree of flexion of the knee and ankle necessitated by the adoption of the squatting position as an attitude of habitual rest is associated with an increase in the convexity of the external condylic surface, and the appearance, not infrequently, of a pressure facet on the anterior border of the lower extremity, which rests in that position on the neck of the astragalus. Cases of congenital absence of the tibia have been frequently described, amongst the most recent being those recorded by Clutton, Joachimsthal, Bland Sutton, and Waitz.

Ossification.—The shaft begins to ossify early in the second month of intrauterine life. At birth it is well formed, and capped above and below by pieces of cartilage, in the upper of which the centre for the superior epiphysis has already usually made its appearance. From this the tuberosities and tubercle are developed, though sometimes an independent centre for the latter appears about the eleventh or twelfth years, rapidly joining with the already well-developed mass of the rest of the epiphysis. Complete fusion between the superior epiphysis and the shaft does not take place until the twentieth or the twenty-fourth year. The centre for the lower articular surface and the internal malleolus makes its appearance about the end of the second year, and union with the shaft is usually complete by the age of eighteen. Lambertz notes the occasional presence of an accessory nucleus in the malleolus.

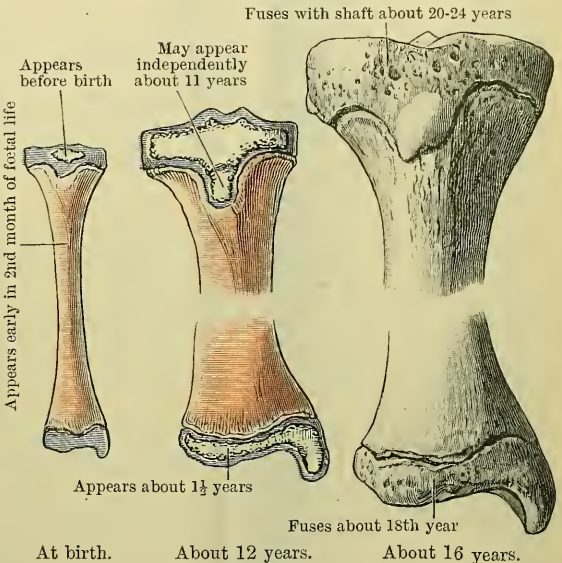


FIG. 177.—OSSIFICATION OF THE TIBIA.

THE FIBULA.

The **fibula**, or **peroneal bone**, is a slender bone with two enlarged ends. It lies to the outer side of the tibia, with which it is firmly united by ligaments, and nearly equals that bone in length.

The first difficulty which the student has to overcome is to determine which is the upper and which the lower extremity of the bone. This can easily be done by recognising the fact that there is a deep pit on the inner aspect of the lower extremity immediately behind the triangular articular surface. Holding the bone vertically with the lower extremity downwards and so turned that the triangular articular area lies in front of the notch already spoken of, the subcutaneous non-articular aspect of the inferior extremity will point to the side to which the bone belongs.

The **superior extremity or head** of the fibula (capitulum fibulæ), of irregular rounded form, is bevelled on its inner surface so as to adapt it to the form of the under surface of the external tuberosity of the tibia. At the border, where this

surface becomes confluent with the outer aspect of the head, there is a pointed upstanding eminence called the **styloid process** (apex capituli fibulæ): to this the short external lateral ligament is attached, as well as a piece of the tendon of the biceps, which is inserted into its fore-part. Immediately to the inner side of this, and occupying the summit of the internal sloping surface, there is an **articular area** (facies articularis capituli), of variable size and more or less triangular shape. This serves for articulation with the external tuberosity of the tibia. The long external lateral ligament, together with the remainder of the tendon of the biceps muscle which surrounds it, is attached to the outer and upper side of the head in front of the styloid process. In front and behind the head there are usually prominent tubercles. The anterior of these is associated with the origin of the peroneus longus muscle; the posterior, whilst furnishing an origin for the upper fibres of the soleus, serves to deepen the groove, behind the superior tibio-fibular articulation, in which the tendon and fleshy part of the popliteus muscle play. The constricted portion of the shaft below the head is often referred to as the **neck**; around the outer side of this the external popliteal nerve winds.

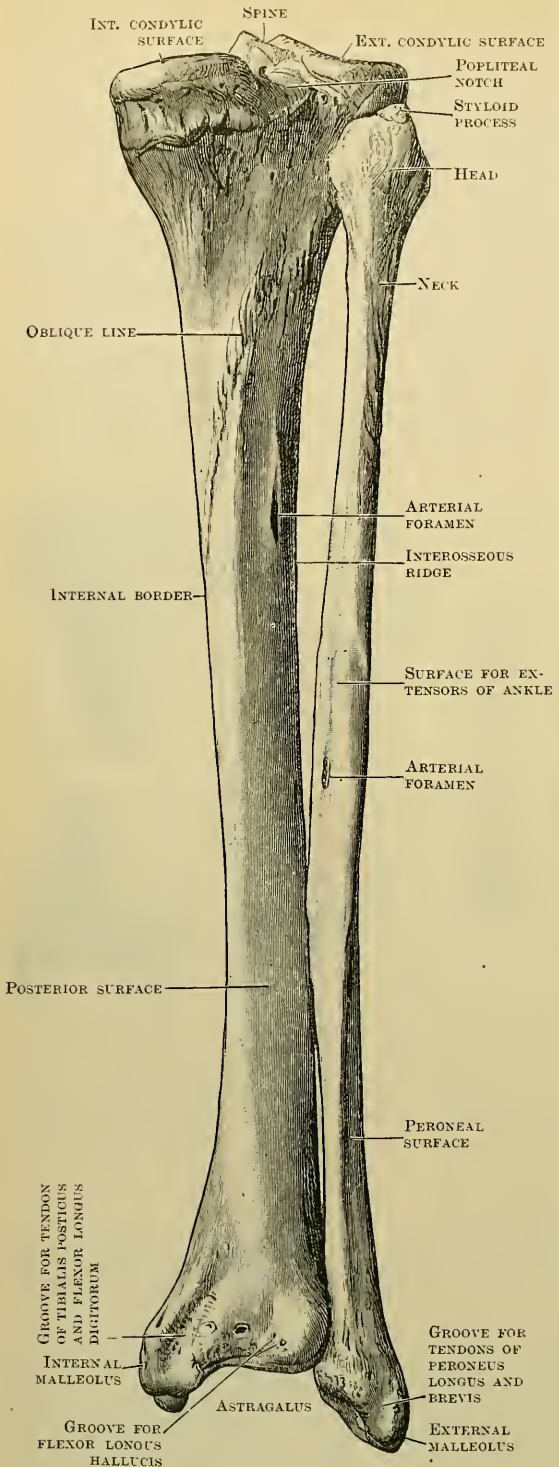


Fig. 178.—Right Tibia and Fibula as seen from Behind.

The **shaft** of the fibula (corpus fibulæ) presents many varieties of shape and form, being ridged and channelled in such a way as greatly to increase the difficulties of the student in recognising the various surfaces described. The most important point is first to determine the position of the interosseous ridge. Holding the bone in the position which it normally occupies in the leg, it will be noticed that the external surface of the lower extremity is limited in front and behind by two lines, which, converging above, enclose between them a triangular subcutaneous area which lies immediately above the outer ankle. From the summit of the triangle so formed a well-defined ridge may be traced up the front of the shaft to reach the anterior aspect of the head. This is the *anterior border*, and must not be mistaken for the inter-

osseous ridge, which is now easy to find, for the next ridge which lies immediately internal to the anterior border, or towards the tibial side on the anterior aspect of the bone, is the line to which the interosseous membrane is attached. As a rule these two lines are separated by a considerable interval in the lower half of the bone, but tend to run much closer together above; indeed it is not uncommon to find that they coalesce to form a single crest. Let it therefore be clear that the interosseous line is that which lies immediately internal to the ridge which springs inferiorly from the malleolar subcutaneous triangular surface, notwithstanding the differences in width of the surface which separates the lines, or their occasional coalescence above.

The position of the interosseous ridge enables us at once to separate the flexor aspect of the bone from its extensor surface, using these terms in relation to the movements of the ankle.

The use of these terms is not, strictly speaking, correct, and they are here used in a physiological and not in a morphological sense. The anterior surface of the leg is the true extensor surface, and is comparable with the posterior surface of the forearm, the change in position having been brought about developmentally by difference in the rotation of the limbs. Flexion of the ankle, so called, is in reality an extensor movement, and corresponds to extension at the wrist. (See Humphry, *Journ. Anat. and Physiol.*, vol. xxviii. p. 15.)

In addition, there is the peroneal surface, which corresponds to the outer side of the shaft. Starting then at the interosseous ridge, and passing forwards round the outer side of the shaft, the **flexor surface** is the first met with; this is bounded externally by the anterior border, and, as has been said, may be either of considerable width or almost linear. From this arises the extensor communis digitorum, together with the peroneus tertius and the extensor proprius hallucis muscles, which, though extensors of the toes, are also *flexors* of the ankle.

The *anterior border* serves for the attachment of the intermuscular septum, which separates the foregoing group of muscles from that which lies along the outer side of the shaft, viz. the peroneus longus and brevis muscles. The surface from which these arise is limited behind by the *posterior border*, which is usually sharp and well defined below, where it is continuous with the bone immediately above the pit on the inner surface of the lower extremity, whilst it tends to be less distinct and more rounded above where it runs into the base of the styloid process. In its upper third or fourth this border is often rough and tubercular where it serves for the origin of the soleus. The **outer** or **peroneal surface** is somewhat twisted, being directed rather forwards above, but tending to turn backwards below where it becomes continuous with the groove which courses along the back of the external malleolus and which lodges the tendons of the peroneus longus and brevis muscles. The remainder of the shaft, included between the posterior border behind and the interosseous ridge in front and internally, is the **extensor surface**, for here arise the several muscles whose action in part is to extend the ankle. This surface is cut up by a curved ridge often the most prominent and outstanding on the bone,

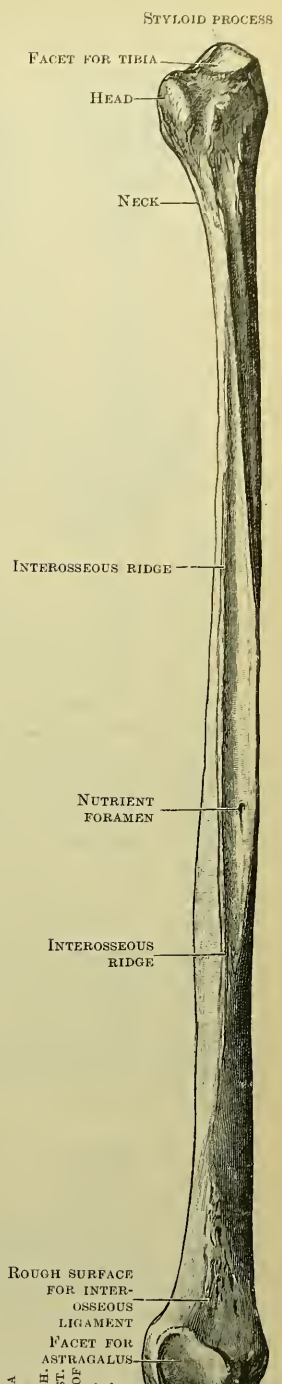


Fig. 179.—Right Fibula as seen from the Inner Side.

and hence frequently mistaken by the student for the interosseous ridge; it serves to define the area for the origin of the tibialis posticus, and arises below from the posterior border of the interosseous ridge at the junction of the middle and inferior thirds of the shaft, curves a little backwards, and passing upwards and obliquely forwards again joins the interosseous ridge once more in the region of the neck. This is oftentimes called the internal border (crista medialis); and the surface so mapped off, the internal surface. The ridge itself serves for the attachment of the aponeurosis which covers the tibialis posticus muscle. The remainder of the extensor aspect of the shaft, which, above, is directed backwards, is so twisted that inferiorly it is directed inwards. From this, in its upper part, the soleus muscle arises; whilst lower down, the flexor longus hallucis muscle derives an extensive origin. Both of these muscles, together with the tibialis posticus, act as *extensors* of the ankle. On this aspect of the bone, at or near the middle of the shaft, and just behind the prominent tibial ridge, is the opening of the nutrient canal, which has a downward direction.

The **inferior extremity** of the fibula, or **external malleolus** (malleolus lateralis), is of pyramidal form. Its inner surface is furnished with a triangular articular area (facies articularis malleoli), plane from before backwards, and slightly convex from above downwards, which articulates with a corresponding surface on the outer side of the body of the astragalus. Behind this there is a deep pit, to which the posterior fasciculus of the external lateral ligament is attached. Above the articular facet there is a rough triangular area on the extensor surface of the shaft, from the summit of which the interosseous ridge arises; hereto are attached the strong fibres of the inferior interosseous ligament which binds together the opposed surfaces of the tibia and fibula. The external surface of the inferior extremity forms the elevation of the external malleolus which determines the shape of the projection of the outer ankle. Rounded from side to side and from above downwards, it terminates below in a pointed process, which reaches a lower level than the corresponding process of the tibia, from which it also differs in being narrower and more pointed and being placed in a plane nearer the heel. Superiorly, this surface, which is subcutaneous, is continuous with the triangular subcutaneous area so clearly defined by the convergence above of the lines which unite to form the anterior border. The anterior border and tip of the external malleolus furnish attachments to the anterior and middle bands of the external lateral ligament of the ankle. The posterior surface of the external malleolus, broad above, where it is confluent with the peroneal or external surface, is reduced in width below by the presence of the pit which lies to its inner side. This aspect of the bone is grooved (sulcus malleolaris) by the tendons of the peroneus longus and brevis muscles, which curve round the posterior and lower-pointed aspect of the malleolus. The proportionate length of the fibula to the body height is as 1 is to 4·37–4·82.

Arterial Foramina.—Numerous minute vascular canals are seen piercing the outer surface of the head, and one or two of larger size are seen on the inner surface immediately in front of the superior articular facet. The canal for the nutrient artery of the shaft, which has a downward direction, is situated on the back of the bone about its middle. The outer surface of the external malleolus displays the openings of many small canals, and one or two larger openings are to be noted at the bottom of the pit behind the inferior articular surface.

Connexions.—The head and external malleolus, and part of the shaft immediately above the latter, are subcutaneous. The remainder of the shaft is covered on all sides by the muscles which surround it. Superiorly the bone plays no part in the formation of the knee-joint, but inferiorly assists materially in strengthening the ankle-joint by its union with the tibia and its articulation with the astragalus. In position the bone is not parallel to the axis of the tibia, but oblique to it, its upper extremity lying posterior and external to a vertical line passing through the external malleolus.

Architecture.—A medullary canal runs throughout the length of the shaft, reaching as high as the neck above, and extending as low as a point about $2\frac{1}{2}$ inches above the inferior extremity of the external malleolus. The outer wall of the shaft is usually considerably thicker than the inner. The head is formed of loose cellular bone, enclosed within a very thin dense envelope. The spongy tissue of the lower extremity is more compact, and acquires considerable density on the surfaces underlying the articular area and the pit behind it. The canal for the nutrient artery of the shaft opens into the medullary cavity about an inch below its external aperture.

Ossification.—The shaft begins to ossify about the middle of the second month of fœtal life. At the end of the third month there is but little difference in size between it and the tibia, and at birth the fibula is much larger in proportion to the size of the tibia than in the adult. Its extremities are cartilaginous, the lower extremity not being as long as the internal malleolar cartilage of the tibia. It is in this, however, that an ossific centre first appears about the end of the second year, which increases rapidly in size, and unites with the shaft about nineteen years. The centre for the superior epiphysis begins to ossify about the third or fourth year, and union with the shaft is not complete until a period somewhat later than that for the inferior epiphysis. The mode of ossification of the lower extremity is an exception to the general rule that epiphyses which are the first to ossify are the last to unite with the shaft.

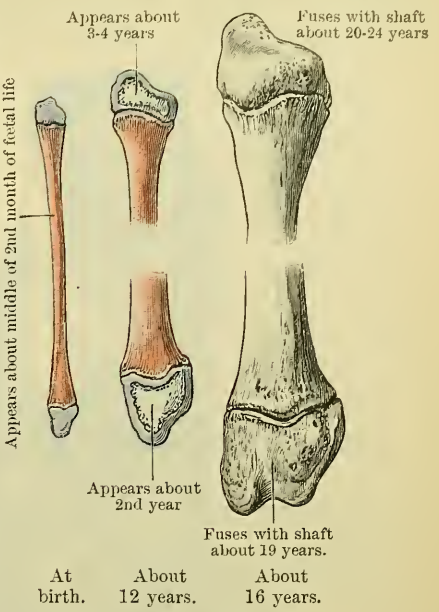


Fig. 180.—Ossification of Fibula.

In its earlier stages of development it has been stated, on the authority of Lebouc̣q, Gegenbaur and others, that the fibula as well as the tibia is in contact with the femur. This is, however, denied by Grunbaum ("Proc. Anat. Soc.," *Journ. Anat. and Physiol.*, vol. xxvi. p. 22), who states that after the sixth week the fibula is not in contact with the femur, and that prior to that date it is impossible to differentiate the tissue which is to form femur from that which forms fibula.

Variations.—The fibula may be ridged and grooved in a remarkable manner, as is the case in many bones of prehistoric races. This is probably associated with a greater or perhaps more active development of the muscles attached to it.

The superior articular facet varies much in size. Bennett (*Dublin Journ. Med. Sc.*, Aug. 1891) records a case in which it was double, and also notes the occurrence of specimens in which it was absent and in which the head of the bone did not reach as high as the tibial tuberosity.

Many instances of partial or complete absence of the bone have been published. (Lefèbre, *Contribution à l'étude de l'absence congénitale du péroné*, Lille, 1895.)

BONES OF THE FOOT.

The bones of the foot, twenty-six in number, are arranged in three groups: the tarsal, seven in number; the metatarsal, five in number; the phalanges, fourteen in number.

Comparing the foot with the hand, the student will be struck with the great proportionate size of the tarsus as compared with the carpus, and the reduction in size of the bones of the toes as compared with the fingers. The size of the metatarsal segment more nearly equals that of the metacarpus.

The Tarsus.

The **tarsus** (ossa tarsi) consists of seven bones—the astragalus, os calcis, navicular or scaphoid, three cuneiforms, and the cuboid. Of irregular form and varying size, they may be described as roughly cubical, presenting for examination dorsal and plantar surfaces as well as anterior, posterior, internal, and external aspects.

The Astragalus.

The **astragalus** (talus) is the bone through which the body weight is transmitted from the leg above to the foot below. Superiorly the tibia rests upon it, whilst on either side it articulates with the internal and external malleolar processes of the tibia and fibula respectively; inferiorly it overlies the os calcis, and anteriorly it articulates with the navicular. For descriptive purposes the bone is divisible into two parts—the **body** (corpus tali) blended in front with the **neck** (collum tali), which supports the **head** (caput tali).

The *upper surface* of the **body** is provided with a saddle-shaped articular surface (trochlea tali), broader in front than behind, for articulation with the under surface of the tibia. The inner edge of the trochlea is straight; whilst the outer border, which is sharp in front and more rounded behind, is curved inwards posteriorly, where it is bevelled to form a narrow, elongated, triangular facet, which is in contact with the transverse or inferior tibio-fibular ligament during flexion of the ankle (Fawcett, *Ed. Med. Journ.*, 1895). Over the outer border the cartilage-covered surface is continuous externally with an extensive area of the form of a quadrant. This is concave from above downwards, and articulates with the inner surface of the fibular malleolus. The inferior angle of this area is prominent and somewhat everted, and sometimes referred to as the **external process** (processus lateralis tali). The inner aspect of the body has a comma-shaped facet, confluent with the superior articular surface, over the inner edge of the trochlea; this articulates with the outer surface of the tibial malleolus. Inferior to this facet the bone is rough and pitted by numerous small openings, and just below the tail of the comma there is a circular impression for the attachment of the deep fibres of the internal lateral ligament. On the *inferior surface* of the body there is a deep concave facet, called the **posterior calcanean facet** (facies calcanea articularis posterior), which is of more or less oval or oblong form and is placed obliquely from behind forwards and outwards; this rests upon a corresponding surface on the upper aspect of the os calcis. In front of this, and crossing the bone from within outwards and forwards, is a deep **furrow** (sulcus tali), the floor of which is pierced by numerous large canals. It serves for the attachment of the

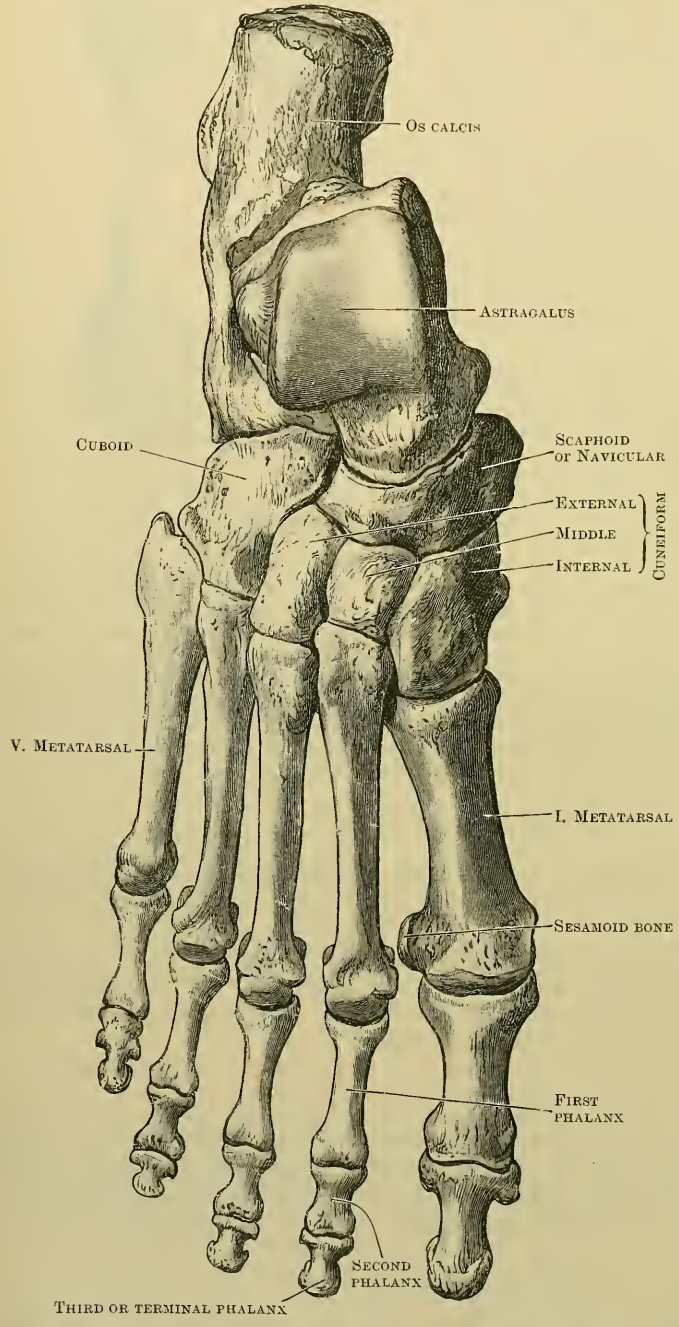


Fig. 181.—Bones of the Right Foot as seen from Above.

strong interosseous ligament which unites the astragalus with the os calcis, and separates the facet already described from a smaller oval articular area having a slightly convex surface, which lies immediately in front of it. This is called the **middle calcanean facet** (facies articularis calcanea media), and articulates with the upper surface of the sustentaculum tali of the os calcis. Posteriorly the body is provided with two tubercles, separated by a groove; the external of these (processus posterior tali) is usually the larger, and is occasionally a separate ossicle (os trigonum). To it is attached the posterior fasciculus of the external lateral ligament of the ankle-joint. The groove, which winds obliquely from above downwards and inwards over the posterior surface of the bone, lodges the tendon of the flexor longus hallucis muscle.

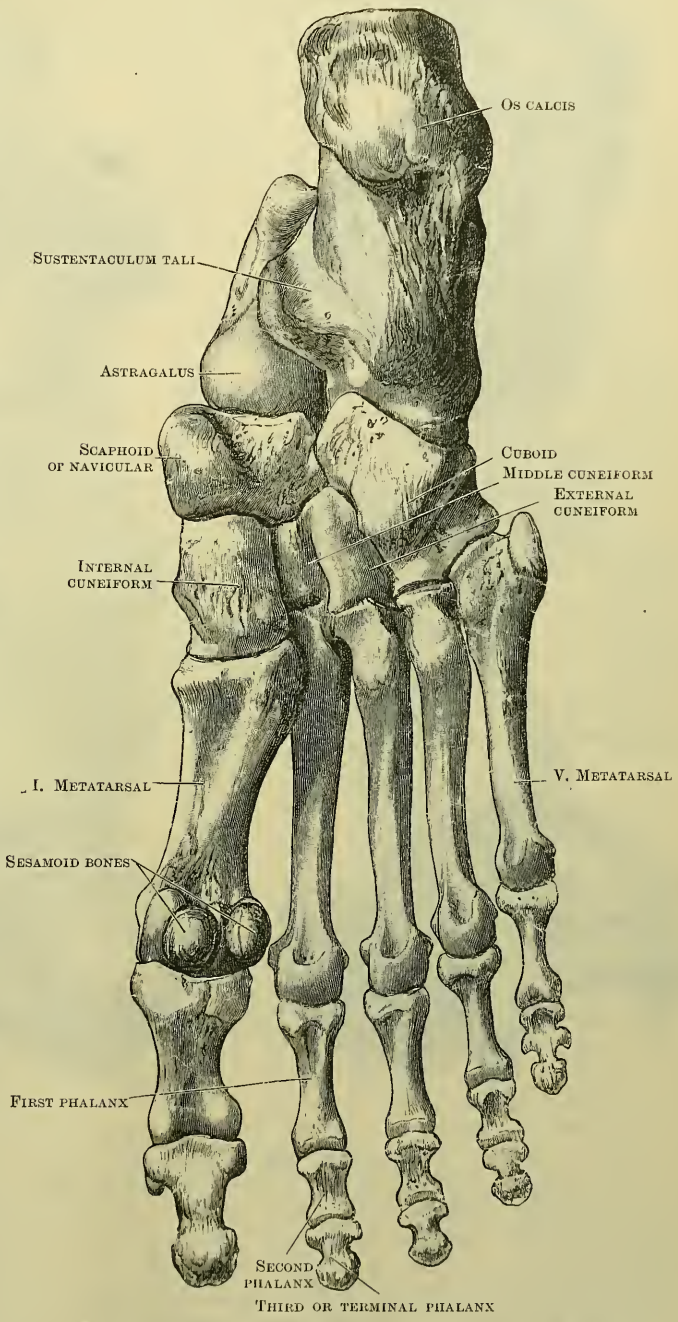


Fig. 182.—Bones of the Right Foot as seen from Below.

The **head** (caput tali), of oval form, is directed forwards and inwards. Its anterior surface is convex from side to side and from above downwards, and articulates with the navicular bone (facies articularis navicularis). Inferiorly this surface is confluent with the middle calcanean facet, but in well-marked specimens, or when the bones are articulated, it will be seen that a small area in front of, and external to, the middle calcanean facet rests upon an articular surface on the upper part of the fore portion of the os calcis, and is called the **anterior calcanean facet** (facies articularis calcanea anterior). To the inner and under surface of the head there is a cartilage-covered surface which does not articulate with any bone, but rests on the upper surface of the inferior calcaneo-navicular ligament, and is supported on the inner

side by the tendon of the tibialis posticus muscle (Fawcett, *Ed. Med. Journ.* 1895, p. 987).

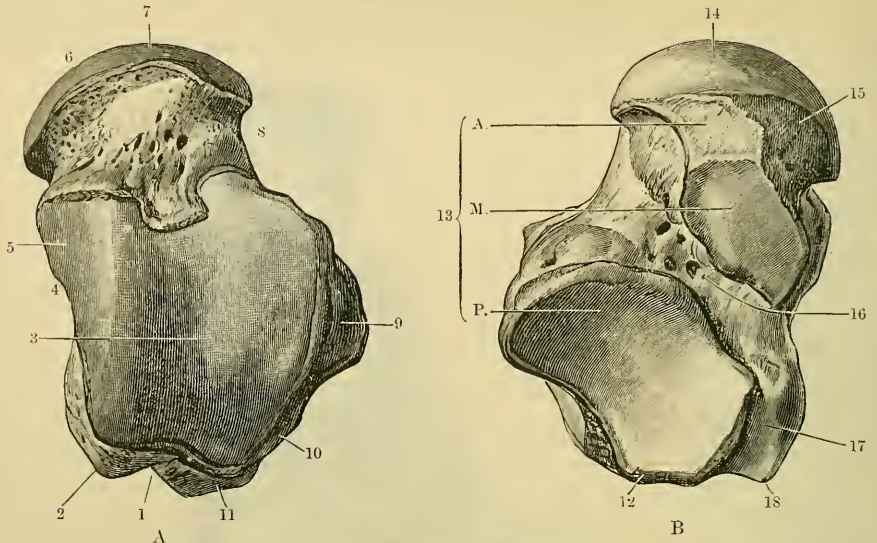


FIG. 183.—THE RIGHT ASTRAGALUS.

A. Upper Surface. B. Under Surface.

1. GROOVE FOR FLEX. LONG. HALLUCIS.
2. INTERNAL TUBERCLE.
3. TROCHLEAR SURFACE FOR TIBIA.
4. BODY.
5. FOR ARTICULATION WITH INTERNAL MALLEOLUS.
6. HEAD.
7. FOR ARTICULATION WITH NAVICULAR.
8. NECK.
9. FOR ARTICULATION WITH EXTERNAL MALLEOLUS.
10. SURFACE AGAINST WHICH THE INFERIOR TIBIO-FIBULAR LIGAMENT RESTS.
11. EXTERNAL TUBERCLE.
12. EXTERNAL TUBERCLE.
13. POSTERIOR, MIDDLE, AND ANTERIOR FACETS FOR OS CALCIS.
14. FOR ARTICULATION WITH NAVICULAR.
15. SURFACE RESTING ON INFERIOR CALCANEO-NAVICULAR LIGAMENT.
16. INTEROSSEOUS GROOVE.
17. INTERNAL TUBERCLE.
18. GROOVE FOR FLEXOR LONGUS HALLUCIS.

The **neck** (collum tali), best seen above, passes from the front of the body and inclines towards the inner side. It is confluent with the inner surface in front of

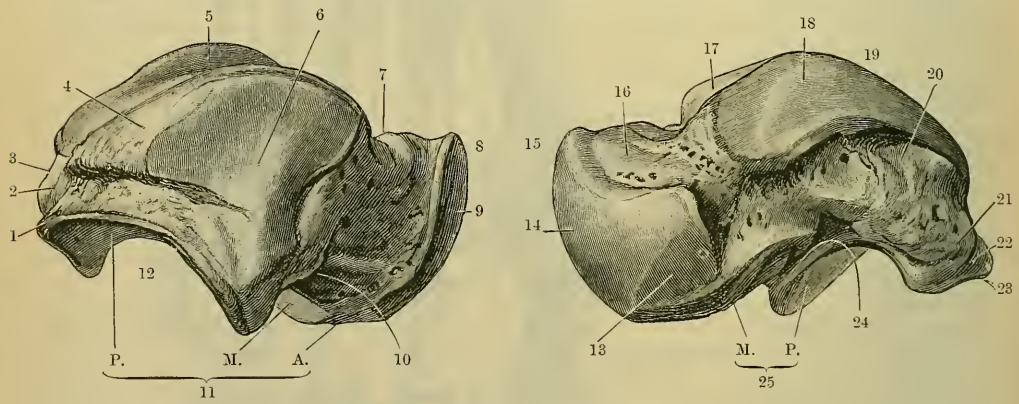


FIG. 184.—THE RIGHT ASTRAGALUS.

A. As seen from the Outer Side. B. As seen from the Inner Side.

1. EXTERNAL TUBERCLE.
2. GROOVE FOR FLEXOR LONGUS HALLUCIS.
3. INTERNAL TUBERCLE.
4. SURFACE AGAINST WHICH THE INFERIOR TIBIO-FIBULAR LIGAMENT RESTS.
5. TROCHLEA FOR TIBIA.
6. FOR ARTICULATION WITH EXTERNAL MALLEOLUS.
7. NECK. 8. HEAD.
9. FOR ARTICULATION WITH NAVICULAR.
10. INTEROSSEOUS GROOVE.
11. ANTERIOR MIDDLE, AND POSTERIOR FACETS FOR OS CALCIS.
12. BODY.
13. SURFACE RESTING ON INTERNAL CALCANEO-NAVICULAR LIGAMENT.
14. FOR ARTICULATION WITH NAVICULAR.
15. HEAD.
16. NECK.
17. TROCHLEA FOR TIBIA.
18. FOR ARTICULATION WITH INTERNAL MALLEOLUS.
19. BODY.
20. IMPRESSION FOR INTERNAL LATERAL LIGAMENT.
21. INTERNAL TUBERCLE.
22. GROOVE FOR FLEXOR LONGUS HALLUCIS.
23. EXTERNAL TUBERCLE.
24. INTEROSSEOUS GROOVE.
25. POSTERIOR AND MIDDLE FACETS FOR OS CALCIS.

the internal malleolar facet, and externally forms a wide groove, which becomes continuous inferiorly with the outer end of the interosseous groove.

Variations.—The anterior is sometimes separated from the middle calcanean facet by a non-articular furrow. The posterior external tubercle, often largely developed, is occasionally (2·6 per cent) a separate ossicle forming what is known as the os trigonum (Bardeleben); or it may be united to the body of the astragalus by a distinct synchondrosis. A smooth articular surface may occasionally be found on the outer side of the upper surface of the neck. This is a pressure facet dependent on the frequent use of the ankle-joint in a condition of extreme flexion, and is caused by the opposition of the bone against the anterior edge of the lower end of the tibia.

For a detailed study of the varieties of this bone, see R. B. S. Sewell (*Journ. Anat. and Physiol.*, vol. xxxviii.)

The Os Calcis.

The **os calcis** (calcaneus) is the largest of the tarsal bones. It supports the astragalus above and articulates with the cuboid in front. Inferiorly and behind, its posterior extremity or tuberosity forms the heel on which so large a proportion of the body weight rests. The long axis of the bone inclines forwards and a little outwards.

The *upper surface* of the os calcis is divisible into two parts—a posterior non-

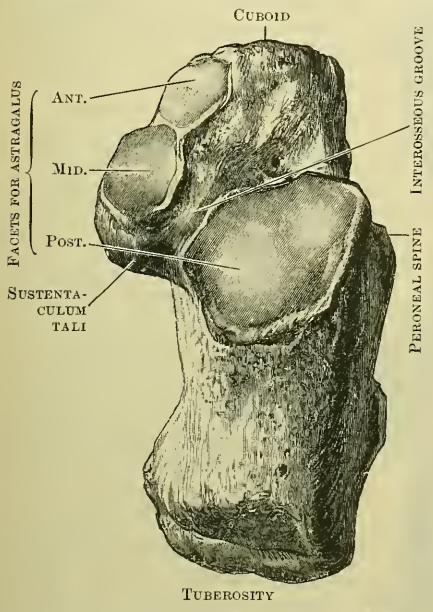


Fig. 185.—The Right Os Calcis as seen from above.

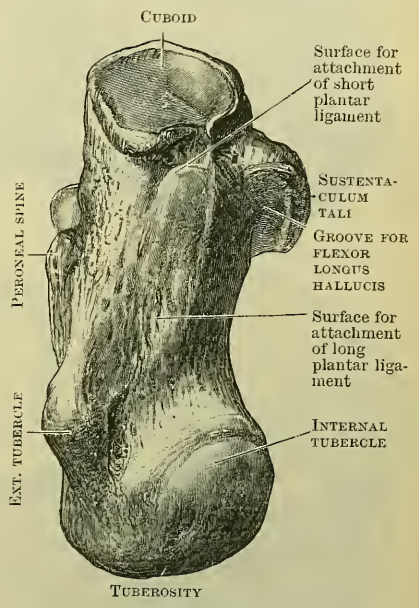
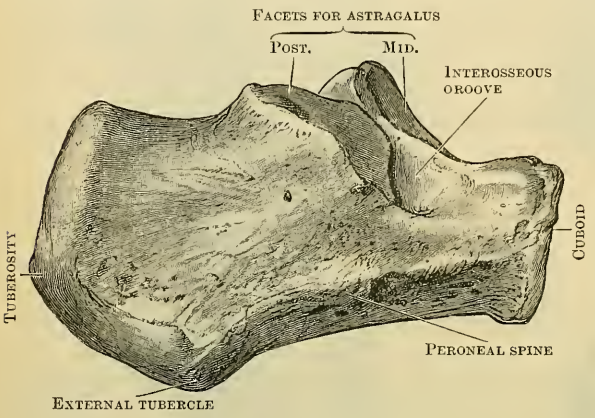


Fig. 186.—The Right Os Calcis as seen from below.

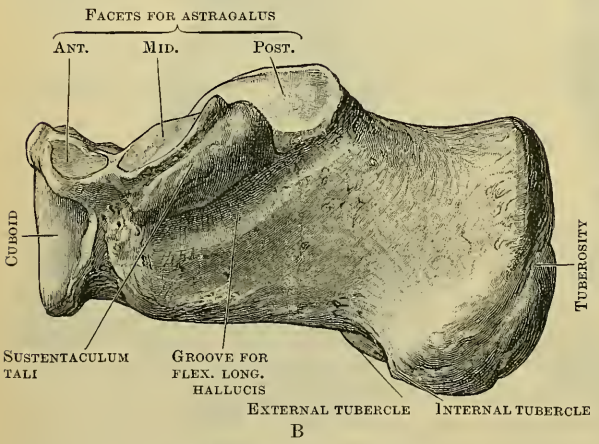
articular part and an anterior articular portion. The length of the former varies according to the projection of the heel; rounded from side to side, it is slightly concave from before backwards. In front of this there is a convex articular area of variable shape (facies articularis posterior), sometimes nearly circular, at other times oval and occasionally almost triangular. This is directed upwards and forwards, and articulates with the posterior calcanean facet on the under surface of the astragalus. Anterior to this facet the bone is deeply excavated, forming a fossa from which a **groove** (sulcus calcanei) leads backwards and inwards around the antero-internal border of the articular surface. When the os calcis is placed in contact with the astragalus, this groove coincides with the sulcus on the under surface of the latter bone, and so forms a **canal** or tunnel (sinus tarsi) in which the strong interosseous ligament which unites the two bones is lodged. To the front and inner side of this groove there is an elongated articular facet directed obliquely from behind forwards and outwards, and concave in the direction of its long axis. This is frequently divided into two smaller oval areas by an intermediate non-articular surface. Of these facets the hinder (facies articularis media) articulates with the middle calcanean facet on the under surface of the astragalus, whilst the anterior (facies articularis anterior) supports the under surface of the head of the astragalus (facies articularis calcanei anterior). The outer side of the upper surface of the

anterior extremity of the bone is rough, and hereto is attached the origin of the short extensor muscle of the toes.

The *inferior surface* of the bone is slightly concave from before backwards, and convex from side to side. The under aspect of the tuberosity is provided with two **tubercles**, an **inner** (processus medialis tuberis calcanei) and an **outer** (processus lateralis tuberis calcanei), of which the former is the larger. From this the short flexor of the toes and the abductor hallucis muscle arise, whilst from both tubercles spring the fibres of origin of the abductor minimi digiti muscle. On the fore-part of the under surface there is an elevated elongated tubercle, which terminates somewhat abruptly just behind the anterior border of this aspect of the bone, giving rise at times to a notch. From the former spring the fibres of the long plantar ligament, whilst the latter serves for the attachment of the deeper fibres of the short plantar ligament. The two heads of origin of the flexor accessorius muscle arise from the bone on either side of the long plantar ligament. The *internal surface* of the os calcis is crossed obliquely, from above downwards and forwards, by a broad groove of considerable depth; along this pass many of the structures which enter the sole of the foot from the back of the leg. The groove is overhung in front and above by a projecting bracket-like process, called the **sustentaculum tali**, or **lesser process**. The under surface of the sustentaculum is channelled by a groove, in which is lodged the tendon of the flexor longus hallucis muscle; whilst its inner border, to which is attached a part of the internal lateral ligament of the ankle, is overlain by tendon of the flexor longus digitorum. To the anterior border of the sustentaculum is attached the inferior calcaneo-navicular ligament, and placed on its upper surface is the articular facet already alluded to (facies articularis media). Posteriorly the internal surface of the bone is limited inferiorly by the projection of the internal tubercle, and above by the internal lipped edge of the tuberosity.



A. As seen from the Outer Side.



B. As seen from the Inner Side.

Fig. 187.—The Right Os Calcis.

The *external surface*, broad behind and narrower in front, is of flattened form. Springing from it, just below the outer end of the sinus tarsi, is the **peroneal spine** (processus trochlearis), often indistinctly marked. To this the fibres of the external annular ligament are attached; whilst in grooves, above and below it, pass the tendons of the peroneus brevis and longus muscles respectively. To the upper and back part of this surface are attached the fibres of the middle fasciculus of the external lateral ligament of the ankle.

The *anterior extremity*, sometimes called the **greater process**, is furnished with a saddle-shaped surface on its anterior aspect for articulation with the cuboid. This

facet is concave from above downwards, and slightly convex from side to side; its edges are sharply defined, except internally, and serve for the attachment of ligaments.

The *posterior extremity*, called the **tuberosity** (tuber calcanei), forms the projection of the heel. Of oval form and rounded surface, it rests upon the two tubercles inferiorly. Its cutaneous aspect is divisible into three areas. Of these the highest is smooth and crescentic, and is covered by a bursa; the intermediate is also fairly smooth, and is defined inferiorly by an irregular line, sometimes a definite ridge, the edges of which are striated. Into this surface the tendo Achillis is inserted. The lowest surface is rough and striated, and is confluent below with the internal and external tubercles; this is overlain by the dense layer of tissue which forms the pad of the heel.

Variations.—The peroneal tubercle is occasionally unduly prominent, constituting the submalleolar apophysis of Hyrtl, and cases are recorded of the os calcis articulating with the navicular (Morestin, H., *Bull. de la Soc. Anat. de Paris*, 1894, ser. v. t. 8, n. 24, p. 798; and Petrini, *Atti del XI. Congr. Med. Internaz. Roma*, 1894, vol. ii., "Anat." p. 71). Pfitzner (*Morphologische Arbeiten*, vol. vi. p. 245) also records the separation of the sustentaculum tali to form an os sustentaculi. (See also P. P. Laidlaw, *Journ. Anat. and Physiol.*, vol. xxxviii. p. 133.)

The Navicular Bone.

The **navicular** or **scaphoid bone** (os naviculare pedis), of compressed pyriform shape, is placed on the inner side of the foot, between the head of the astragalus posteriorly and the three cuneiform bones anteriorly. The bone derives its name from the oval or boat-shaped hollow on its *posterior surface*, which rests upon the head of the astragalus. Its *anterior aspect* is furnished with a semilunar articular area, which is subdivided by two faint ridges into three wedge-shaped facets for articulation from within outwards with the internal, middle, and external cuneiform bones. *Superiorly* the surface of the bone, convex from side to side, is rough for the attachment of the ligaments on the dorsal aspect of the foot. *Inferiorly* the bone is irregularly concave, and marked by the attachment of the plantar ligaments. The *external surface* is narrow from before backwards, and rounded from above downwards. Usually devoid of any articular surface, it is occasionally provided with a facet which rests upon a corresponding area on the cuboid. The *inner side* of the bone projects beyond the general line of the inner border of the foot, so as to form a thick rounded **tubercle** (tuberositas oss. navicularis), the position of which can be easily determined in the living. To the inner and under surface of this process an extensive portion of the tendon of the tibialis posticus muscle is inserted.

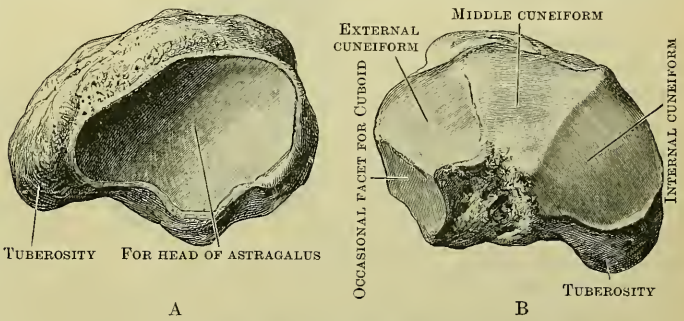


Fig. 188.—The Right Navicular Bone.

A. As seen from Behind; B. As seen from the Front.

Variations.—Cases are recorded where the tubercle has formed an independent ossicle.

The Cuneiform Bones.

The **cuneiform bones**, three in number, are placed between the navicular posteriorly and the bases of the first, second, and third metatarsal bones anteriorly, for which reason they are frequently named the first, second, and third cuneiforms, or, from their position, internal, middle, and external. More or less wedge-shaped, as their name implies, the internal or first is the largest, whilst the middle or

second is the smallest of the group. Combined, they form a compact mass, the proximal surface of which, fairly regular in outline, rests on the anterior surface of the navicular; whilst anteriorly they form a base of support for the three inner metatarsals, the outline of which is irregular, owing to the base of the second metatarsal bone being recessed between the inner and outer cuneiforms as it articulates with the distal extremity of the shorter middle cuneiform.

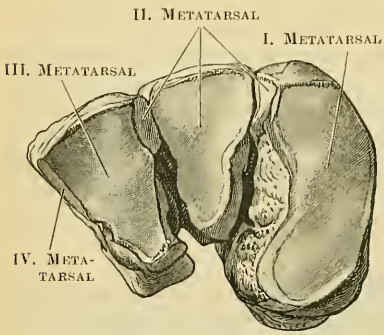


Fig. 189.—Anterior View of the three Cuneiform Bones of the Right Foot.

The **internal cuneiform bone** (os cuneiforme primum), the largest of the three, lies on the inner border of the foot between the base of the metatarsal bone of the great toe in front, and the fore and inner part of the navicular behind. Its *upper*, *lower*, and *internal* surfaces are confluent, and form a convexity from above downwards, which is most pronounced inferiorly, where it is turned towards the plantar side of the foot. On the fore-part of the inner aspect of the bone there is usually a distinct oval impression, which indicates the surface of insertion of a portion of the tendon of the tibialis anticus muscle. Elsewhere this surface is rough for ligamentous attachments. The *external surface* of the bone, quadrilateral in shape, is directed towards the middle cuneiform; but as it exceeds it in length, it also comes in contact with the inner side of the base of the second metatarsal bone. Running along the posterior and upper edges of this area is an ⌐-shaped articular surface, the fore and upper part of which is for the base of the second metatarsal bone, the remainder articulating with the inner side of the middle cuneiform. The non-articular part of this aspect of the bone is rough for the attachment of the strong interosseous ligaments which bind it to the middle cuneiform and second metatarsal bones respectively. The *posterior* or *proximal end* of the bone is provided with a pyriform facet which fits on the inner articular area of the navicular. *Anteriorly* the vertical diameter of the bone is much increased, and the facet for the base of the metatarsal bone of the great toe is consequently much larger than that for the navicular. The metatarsal facet is usually of semilunar form, but not infrequently is more reniform in shape, and may in some cases display complete separation into two oval portions.

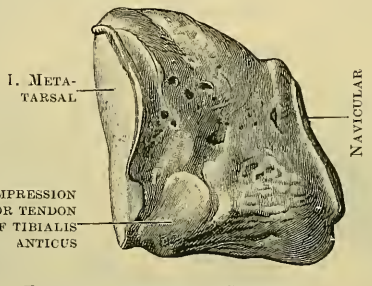


Fig. 190.—The Right Internal Cuneiform (Inner Side).

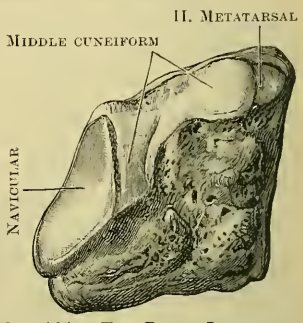


Fig. 191.—The Right Internal Cuneiform (Outer Side).

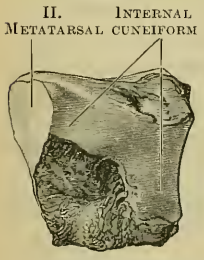


Fig. 192.—The Right Middle Cuneiform (Inner Side).

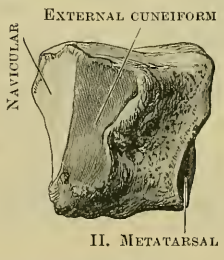


Fig. 193.—The Right Middle Cuneiform (Outer Side).

The **middle** or **second cuneiform** (os cuneiforme secundum) is of a typical wedge shape; shorter than the others it lies between them, articulating with the base of the second metatarsal in front, and the middle facet on the anterior surface of the navicular behind. Its *upper aspect*, which corresponds to the base of the wedge, conforms to the roundness of the instep, and is slightly convex from side to side, affording attachments for the dorsal ligaments. Its under surface is narrow and tubercular, forming the edge

of the wedge; with this the plantar ligaments are connected. The *inner surface*, quadrilateral in outline, is furnished with an Γ-shaped articular area along its posterior and superior borders in correspondence with the similar area on the outer side of the internal cuneiform. The rest of this aspect is rough for ligaments. The *outer side* displays a facet arranged along its posterior border, and usually somewhat constricted in the middle; this is for the external cuneiform. In front of this the bone is rough for the interosseous ligaments, which bind the two bones together. The proximal end is provided with a triangular facet slightly concave from above downwards; this rests on the central articular surface on the anterior aspect of the navicular. In front the bone articulates by means of a wedge-shaped facet with the base of the metatarsal bone of the second toe.

The **external** or **third cuneiform** (os cuneiforme tertium) intermediate in size between the first and second, is also of a typical wedge shape. Its *superior surface*, slightly convex from side to side, provides attachments for the dorsal ligaments. Its *inferior* or *plantar aspect* is narrow and tubercular, and serves for the attachment of the plantar ligaments. Its *inner side*, of quadrilateral form, displays two narrow articular strips, placed along its anterior and posterior borders respectively, each somewhat constricted in the middle. The anterior articulates with the outer side of the base of the second metatarsal bone, the posterior with the outer side of the middle cuneiform. The rough non-articular surface, which separates the two elongated facets, serves for the attachment of ligaments. The *outer aspect* of the bone is characterised by a large circular or oval facet, placed near its hinder border, for articulation with the cuboid; in front of this the anterior border is lipped above by a small semi-oval facet for articulation with the inner side of the base of the fourth metatarsal. The rest of the bone around and between these facets is rough for ligaments. *Proximally* the bone is furnished with a triangular facet for articulation with the outer wedge-shaped area on the front of the navicular, whilst *distally* it articulates with the base of the third metatarsal by a surface of corresponding shape.

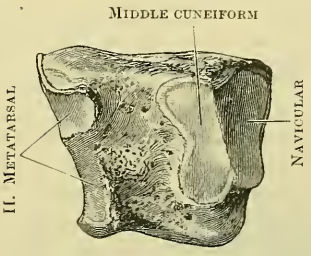


Fig. 194.—Right External Cuneiform (Inner Side).

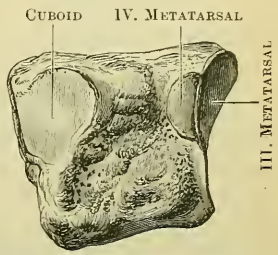


Fig. 195.—Right External Cuneiform (Outer Side).

Variations.—Numerous cases of division of the internal cuneiform bone into dorsal and plantar parts have been recorded; the frequent division of its metatarsal articular facet is no doubt correlated with this anomalous condition. T. Dwight has described (*Anat. Anz.*, vol. xx. p. 465) in two instances the occurrence of an Os Intercuneiforme. The ossicle so named lies on the dorsum of the foot at the proximal end of the line of articulation between the internal and middle cuneiform bones.

The Cuboid Bone.

The **cuboid** (os cuboideum) lies on the outer side of the foot, about its middle, articulating with the os calcis behind and the fourth and fifth metatarsal bones in front. Its *upper surface*, plane in an antero-posterior direction, is slightly rounded from side to side, and provides attachment for ligaments. Its *plantar aspect* is traversed obliquely from without inwards and forwards by a thick and prominent ridge, the outer extremity of which, at the point where it is confluent with the outer surface, forms a prominent **tubercle** (tuberositas oss. cuboidei), the anterior and external surface of which is smooth and faceted to allow of the play of a sesamoid bone which is frequently developed in the tendon of the peroneus longus muscle. In front of this ridge there is a groove (sulcus peronæi) in which the tendon of the peroneus longus muscle is lodged as it passes across the under surface of the bone. Behind the ridge the bone is rough, and serves for the attachment of the short plantar ligament, the superficial fibres of which pass forwards and are attached to the summit of the ridge. The *outer aspect* of the bone

is short and rounded, and is formed by the confluence of the superior and inferior surfaces; it is more or less notched by the peroneal groove which turns round its lower edge. The *internal surface* of the bone is the most extensive; it is easily recognisable on account of the presence of a rounded or oval facet situated near its middle and close to its upper border. This is for articulation with the outer side of the external cuneiform; in front and behind this the surface is rough for ligaments. Not infrequently behind the facet for the external cuneiform there is a small articular surface for the navicular, as is the case normally in the gorilla, whilst behind and below the projecting inferior angle is sometimes provided with a facet on which the head of the astragalus rests (Sutton, "Proc. Anat. Soc.," *Jour. Anat. and Physiol.*, vol. xxvi. p. 18). The *anterior surface* is oval or conical in outline; sloping obliquely from within outwards and backwards, it is divided about its middle by a slight vertical ridge into two parts, the inner of which articulates with the base of the fourth metatarsal bone, the outer with that of the fifth. The *posterior surface,* also articular, has a semilunar outline, the convex margin of which corresponds to the dorsal roundness of the bone. The inferior external angle corresponds to the tubercle on the outer border of the bone, whilst the inferior internal angle forms a pointed projection which is sometimes called the calcanean process. The posterior surface articulates with the os calcis by means of a saddle-shaped facet, which is convex from side to side, and concave from above downwards.

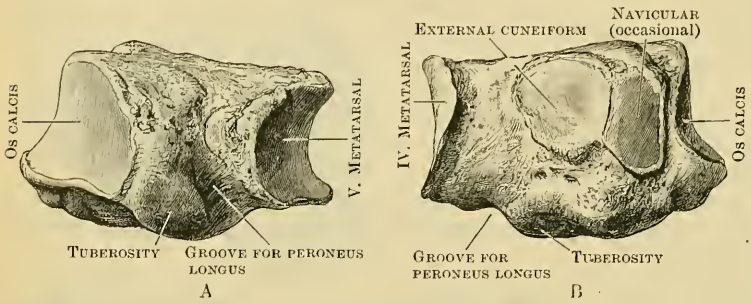


Fig. 196.—The Right Cuboid Bone.

A. Outer Side. B. Inner Side.

Variations.—Blandin has recorded a case of division of the cuboid.

The **tarsus as a whole** may be conveniently described as arranged in two columns; the inner, corresponding to the inner border of the foot, comprising the astragalus, navicular, and three cuneiforms, and forming a base for the support of the three inner metatarsal bones and their phalanges. The outer column, formed by the os calcis and cuboid, supports the fourth and fifth metatarsal bones together with their phalanges. The superior surface of the anterior portion of the tarsus determines the side-to-side roundness of the instep, whilst its under surface forms arches in both a transverse and longitudinal direction, in which the softer tissues of the sole are lodged, and so protected from injury.

Architecture of the Bones of the Foot.—A longitudinal section through the articulated bones of the foot reveals the fact that the cancellous structure of each individual bone is determined by the stress to which it is habitually subjected. In this connexion it is necessary to refer to the arched arrangement of the bones of the foot, a subject which is also treated in the section which deals with the Joints. The summit of the arch is formed by the astragalus, on which rests the tibia. Subjected as the astragalus is to a crushing strain, it is obvious that this load must be distributed throughout the arch, of which the os calcis is the posterior pillar, whilst the heads of the metatarsal bones constitute the anterior pillar. It is found, consequently, that the lamellæ of the cancellous tissue of the astragalus are arranged in two directions, which intercross and terminate below the superior articular surface. Of these fibres, some sweep backwards and downwards towards the posterior calcanean facet, beyond which they are carried in the substance of the os calcis in a curved and wavy manner in the direction of the heel, where they terminate; whilst others, curving downwards and forwards from the trochlea of the astragalus, pass through the neck to reach the articular surface of the head, through which in like manner they may be regarded as passing onwards through the several bones which constitute the anterior part of the arch, thus accounting for the longitudinal striation as displayed in the structure of the navicular, cuneiform, and metatarsal bones. In the os calcis, in addition to the foregoing arrangement, another set of curving fibres sweep from back to front of the bone beneath the more compact tissue which forms its under shell. These are obviously of advantage to prevent the spread of the bone when subjected to the crushing strain. In the sustentaculum tali a bracket-like arrangement of fibres is evident, and the under surface of the neck of the astragalus is further strengthened by lamellæ arranged vertically.

In the separate bones the investing envelope is thin, though under the articular surfaces there is a greater density, due to the accession of lamellæ lying parallel to the articular planes.

The stoutest bony tissue in the astragalus is met with in the region of the under surface of the neck, whilst in the os calcis the greatest density occurs along the floor of the sinus tarsi.

Numerical Variation in the Tarsus.—**Increase in the number** of the tarsal elements may be due to the occurrence of division of either the internal cuneiform or the cuboid bone, or to the occasional presence of an os trigonum. Cases of separation of the tuberosity of the navicular bone have been recorded, and instances of supernumerary ossicles between the internal cuneiform and second metatarsal bone have been noted. Stieda mentions the occurrence of a small ossicle in connexion with the articular surface on the fore and upper part of the os calcis, and Pfitzner notes the occurrence of an os sustentaculi. For further information on the variations of the skeleton of the foot, see Pfitzner (*Morphologische Arbeiten*, vol. vi. p. 245).

The possibility of an injury having been the cause of the occurrence of some of these so-called supernumerary ossicles must not be overlooked. The use of the Röntgen rays has proved that accidents of this kind are much more frequent than was at first supposed.

The **reduction in the number** of the tarsus is due to the osseous union of adjacent bones. In many instances this is undoubtedly pathological, but cases have been noticed (Lebouc) of fusion of the cartilaginous elements of the os calcis and astragalus, and the os calcis and navicular in fœtuses of the third month.

Ossification.—Unlike the carpus, the tarsus is at birth partially ossified. At this period there is a well-marked osseous nucleus within the body and neck of the astragalus, and the os calcis is extensively ossified. In the latter the deposition of earthy matter appears as early as the sixth month of fœtal life, whilst in the astragalus the ossific centre makes its appearance in the later weeks of gestation. Shortly before or after birth the

A B

FIG. 197.—RADIOGRAPHS OF THE FŒTAL FOOT.

A. Between the seventh and eighth months. Here the ossific nuclei of the os calcis and astragalus are seen.
B. At birth. The centres of ossification for the os calcis and astragalus are well developed, the nucleus for the cuboid is quite distinct, and in this instance the external cuneiform is already commencing to ossify. Compare this figure with Fig. 155, in which the carpus is shown as still cartilaginous at birth.

cuboid begins to ossify, succeeded early in the first year by the external cuneiform, followed in order by the middle cuneiform, internal cuneiform, and navicular. The ossific centre of the latter appears at the third year or somewhat later. An epiphysis, which forms a cap over the extremity of the great tuberosity of the os calcis, appears from the seventh to the ninth year, and fusion is completed between the ages of sixteen and twenty.

THE METATARSUS.

The **metatarsal bones**, five in number, in their general configuration resemble the metacarpus. They are, however, slightly longer, their bases are proportionately

larger, their shafts more slender and laterally compressed, and their heads proportionately smaller. They are named numerically the first, second, third, fourth, and fifth metatarsal bones, in order from within outwards. The first can be readily recognised on account of its stoutness; it is also the shortest of the series. The second is the longest of the five, and the fifth can easily be distinguished by the projecting tubercle at its base.

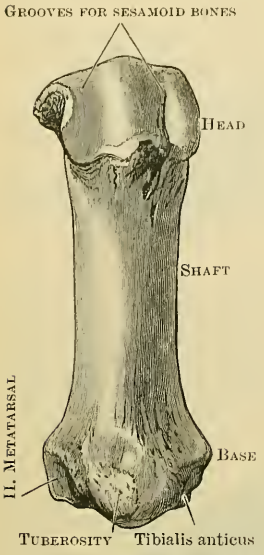


Fig. 198.—The First Metatarsal Bone of the Right Foot (Plantar Aspect).

The **first metatarsal** or metatarsal bone of the great toe, the shortest of the series, is remarkable for its stoutness. Its base, where the bone is provided with a reniform facet for articulation with the internal cuneiform, is wider from before backwards than from side to side. As a rule there are no facets on the lateral aspects of the base. The inferior angle projects backwards and outwards, and forms a prominent tubercle which is pitted for the insertion of the tendon of the peroneus longus muscle, whilst its internal margin is lipped by a surface for the attachment of part of the tendon of the tibialis anticus. The shaft, short, thick, and prismatic on section, tapers rapidly towards the head, the fore and under surfaces of which are articular. The former is convex from side to side, and from above downwards, and supports the proximal phalanx. It is confluent below with the inferior articular surface, which is divided by a median ridge into two shallow grooves, of which the inner is the wider. In these grooves are lodged the two sesamoid bones which underlie the metatarso-phalangeal joint. On either side of the head the bone is pitted for the strong lateral ligaments of the joint.

The **second metatarsal**, the longest of the series, has a base of wedge-shaped form, the proximal aspect of which articulates with the middle cuneiform. On its

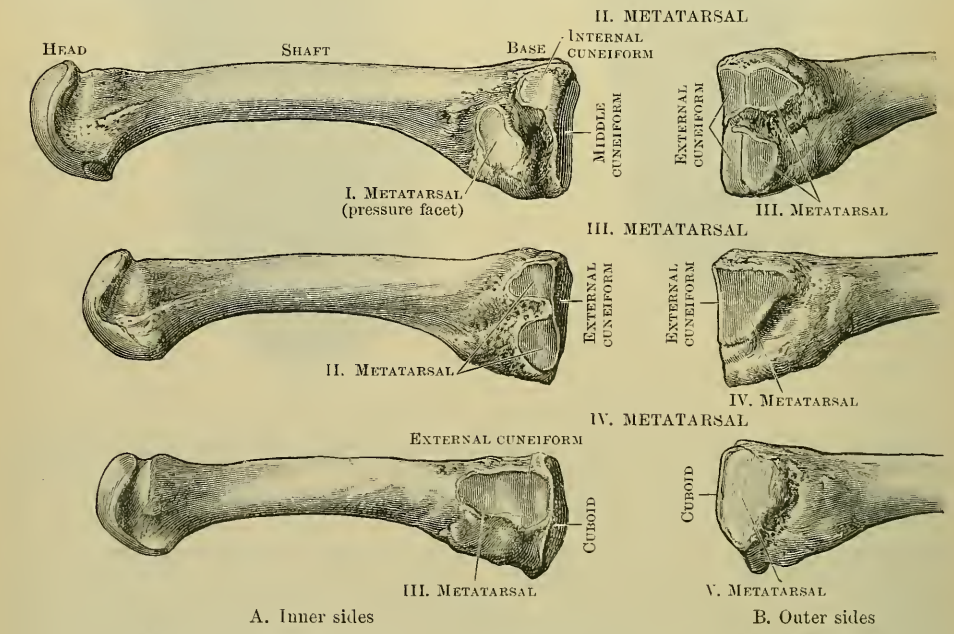


Fig. 199.—View of the Bases and Shafts of the Second, Third, and Fourth Metatarsal Bones of the Right Foot.

inner aspect, near its superior edge, there is a small circular facet for the internal cuneiform; below and in front of this there is sometimes a tubercle with a "pressure" facet on it, where the bone comes in contact with the base of the first metatarsal. On the outer side of the base there is one, more usually two small

facets, each divided into two parts, a posterior for articulation with the external cuneiform, and an anterior for the base of the third metatarsal. The shafts of this and the three succeeding bones are slender and laterally compressed. The heads are small and narrow, and display a pronounced side-to-side and vertical convexity.

The **third metatarsal bone** also possesses a base of wedge-shaped form, the proximal surface of which articulates with the external cuneiform. On its inner side it is provided with one, more usually two, small facets, for articulation with the base of the second metatarsal. Externally the base has a larger facet for articulation with the base of the fourth metatarsal, more or less conical in outline, and having its lower edge sharply defined by a narrow groove which underlies it.

The **fourth metatarsal** has a base more cubical in shape. Its proximal aspect articulates with the cuboid, whilst internally an elongated oval facet, divided by a slight vertical ridge, provides surfaces for articulation with the third metatarsal in front and the outer side of the internal cuneiform behind. On the outer side there is a demi-oval facet, bearing a slightly saddle-shaped surface, for articulation with the inner side of the base of the fifth metatarsal.

The **fifth metatarsal** can be readily recognised by the peculiar shape of its base, from the outer side of which there projects backwards and outwards a prominent tubercle (tuberositas oss. metacarpi V.) To the hinder extremity of this is attached the tendon of the peroneus brevis muscle. To its upper surface the tendon of the peroneus tertius is inserted, whilst its under surface provides an origin for the flexor brevis minimi digiti muscle. The inner surface of the base is provided with a demi-oval, slightly concave facet, for the outer side of the base of the fourth metatarsal, whilst proximally it articulates with the cuboid by means of a semicircular facet.

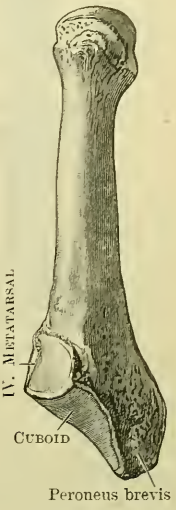


Fig. 200.—Fifth Right Metatarsal Bone (Dorsal Aspect).

Vascular Foramina.—The canals for the nutrient vessels open, as a rule, on the plantar aspects of the middle of the shafts. Those of the outer metatarsals are directed towards the bases of the bones, whilst that for the metatarsal of the great toe passes towards its head.

Architecture.—In structure and the arrangement of their lamellæ the metatarsal bones agree with the metacarpus.

Variations.—Several instances of separation of the tuberosity of the fifth metatarsal (os Vesaleanum) have been recorded, whilst numerous examples of an os intermetatarsum between the bases of the first and second metatarsal bones have been recorded by Gruber and others. The tubercle on the base of the first metatarsal for the attachment of the peroneus longus tendon is occasionally met with as a separate ossicle.

Ossification.—In correspondence with the mode of ossification which maintains in the metacarpus, the primary centres for the metatarsus appear as early as the third month of fœtal life. In the case of the second, third, fourth, and fifth, these centres furnish the bases and shafts of the bones, the heads being developed from secondary centres which appear from two to four years after birth, fusion with the shaft being usually completed about the eighteenth year. In striking contrast to this is the mode of ossification of the first metatarsal. From its primary centre the head and shaft is developed; the secondary centre appears at its **base** about the second or third year, and fuses with the shaft about eighteen. In this respect, therefore, the metatarsal bone of the great toe resembles in its mode of development the phalanges. Mayet, however (*Bull. Soc. Anat. Paris*, 1895), describes the occurrence of two ossific centres in the proximal epiphysis. These fuse early, and he considers that the one represents the metatarsal element, whilst the other may be regarded as phalangeal in its origin.

The Phalanges.

The **phalanges** of the toes (phalanges digitorum pedis) differ from those of the fingers in the striking reduction of their size, and in the case of the bones of the first row, in the lateral compression of their shafts. Each toe is provided normally with three phalanges, except the great toe, which has only two. In their general configuration and in the arrangement of their articular facets they resemble the

digital phalanges, though, owing to the reduction in their size, the shafts, particularly those of the second row, are often so compressed longitudinally as to reduce the bone to a mere nodule. The proximal end of each of the bones of the first row is proportionately large, and is provided with a simple hollow in which the head of the metatarsal bone rests; the distal ends are furnished with condyloid surfaces. The proximal extremities of the second row are each provided with two small concavities, separated by a slight ridge for articulation with the condyles of the first row. The joint between the second and third row displays the same arrangement—the third, terminal or ungual phalanx, being easily distinguished by the spatula-shaped surface at its extremity on which the bed of the nail is supported.

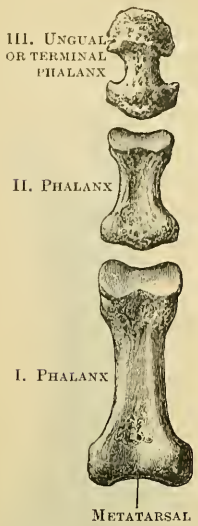


Fig. 201.—The Phalanges of the Toes (Dorsal Aspect).

The phalanges of the great toe, two in number, differ from the others in their size and length. Into the base of the first phalanx are inserted the short muscles of the great toe, whilst the second phalanx receives on its plantar aspect the insertion of the flexor longus hallucis muscle, the tendon of the extensor longus hallucis being inserted into the dorsal aspect.

Architecture.—In their general structure they resemble the bones of the fingers.

Variations.—It is not uncommon to meet with fusion of the second and third phalanges, particularly in the fifth, less frequently in the fourth, and occasionally in the second and third toes. The union of the phalangeal elements has been observed in the fœtus as well as the adult (Pfitzner). The proportionate length of the phalanges varies much; in some cases the ungual phalanges are of fair size, the bones of the second row being mere nodules, whilst in other instances the reduction in size of the terminal phalanges is most marked.

Ossification.—Each phalanx is developed from two centres—one primary for the shaft and distal extremity, the other for the epiphysis on the proximal end. The primary centres for the ungual phalanges are the first to appear, commencing to ossify from the eleventh to the twelfth week of fœtal life. The centre for the ungual phalanx of the great toe makes its appearance before that of its corresponding metatarsal bone. The primary centres for the phalanges of the first row appear from the fourteenth to the sixteenth week. The primary centres for the middle phalanges of the second and third toes begin to ossify about the sixth month, those for the fourth and fifth toes not till later—the shaft of the middle phalanx of the fourth toe being frequently cartilaginous at birth, the normal condition in the case of the fifth toe (Lambertz). The proximal epiphyses do not begin to ossify until about the fourth year, and are usually fused with the diaphyses about the age of sixteen or eighteen. Union between the shafts and epiphyses of the first row precedes that of the second and third rows.

Fig. 202.

A. About the end of the third month. The primary centres of all the metacarpus are shown as well as the centres for the phalanges of the great toe and the terminal phalanx of the third toe.

B.[1] A little later. The centres for the terminal phalanges of the four inner toes are seen, as well as the centres for the first phalanges of the great and second toe.

C. About the fourth month. The centres for all the terminal phalanges as well as those of the first row are well ossified.

D. About the fifth month. In this the centre for the second phalanx of the second toe has already made its appearance.

[1] This specimen displays the occurrence of anomalous centres within the tarsus the significance of which is not apparent. The appearance is not due to any defect in the plate but recurred in repeated skiographs.

Sesamoid Bones.

As in the hand, small independent nodules of bone, called **sesamoid bones**, are met with in the ligaments and tendons of the foot. The most constant of these are found in connexion with the metatarso-phalangeal articulation of the great toe, where they lie in grooves on the under surface of the head of the metatarsal bone in connexion with the tendons of the short muscles of the great toe. Small osseous nodules occupying a corresponding position are occasionally met with in the other toes, and instances have been recorded of like ossicles occurring on the plantar aspect of the interphalangeal joint of the great toe.

An osseous nodule is not infrequently met with in the tendon of the peroneus longus as it turns round the outer border of the foot to lie in the groove on the under surface of the cuboid.

MORPHOLOGY OF LIMBS.

Development and Morphology of the Appendicular Skeleton.

The paired limbs first appear in the human embryo about the third week as small buds on either side of the cephalic and caudal ends of the trunk. That these outgrowths are derived from a large number of trunk segments is assumed on the ground that they are supplied by a corresponding number of segmental nerves, and the circumstance that they are more particularly associated with the ventral offsets of these nerves would point to the conclusion that they belong rather to the ventral than the dorsal surface of the body.

At first the surfaces of these limb buds are so disposed as to be directed ventrally and dorsally, the ventral aspect corresponding to the future flexor surface of the limb, the dorsal to the extensor side. At the same time, the borders are directed headwards (pre-axial), and tailwards (post-axial). As the limbs grow, they soon display evidence of division into segments corresponding to the hand and foot, forearm and leg, upper arm and thigh. Coincident with this (about the second month) the cartilaginous framework of the limb is being differentiated. The disposition of these cartilages furnishes a clue to their homologies. In the fore limb the radius and thumb lie along the pre-axial borders, and correspond to the tibia and great toe, which are similarly disposed in the hind limb; whilst the ulna and fifth finger are homologous with the fibula and fifth toe, which are in like manner arranged in relation to the posterior (post-axial) border of their respective limbs. Up to this time the limbs are directed obliquely ventralwards from the head towards the tail-end of the embryo. During the third month, however, a change in their position takes place, owing to their axes being rotated in opposite directions. The fore limb is turned outwards and forwards to the extent of 90°, whilst the lower hind limb is twisted inwards and backwards to a corresponding degree. This gives rise to a change in the disposition of the joints of the flexor and extensor surfaces. The flexor surface of the elbow is now directed forwards, whilst the corresponding aspect of the knee is turned backwards, and in consequence the dorsal or extensor aspect of the fore limb is posterior, whilst the dorsal or extensor aspect of the hind limb has become anterior. Correspondingly, the pre-axial border of the fore limb with the thumb now lies external, whilst the pre-axial border of the hind limb with the great toe has become internal. A knowledge of these changes is necessary to account for the homologies of the various structures within the limb. In the axial mesoderm of each member, differentiation into cartilaginous segments begins about the second month; each of these cartilages becomes invested by a perichondrial layer which stretches from segment to segment, and ultimately forms the ligaments surrounding the joints, which are subsequently developed between the segments. Chondrification first begins in the basal part of the limb, and extends towards the digits. In the upper arm and thigh the humerus and femur are homodynamous. In the forearm and leg the pre-axial radius corresponds with the pre-axial tibia, and the post-axial ulna with the post-axial fibula. The homodynamy of the carpal and tarsal elements may be tabularly expressed, and compared with the more generalised types from which they are evolved.

Type.	Hand.	Foot.
Radiale (Tibiale)	= Scaphoid (body)	= Astragalus.
Intermedium	= Semilunar	= Absent, or Os trigonum (?)
Ulnare (Fibulare)	= Cuneiform	= Os Calcis.
Centrale	= Absent, or Tubercle on Scaphoid	= Navicular.
Carpale (Tarsale), i.	= Trapezium	= Internal Cuneiform.
Carpale (Tarsale), ii.	= Trapezoid	= Middle Cuneiform.
Carpale (Tarsale), iii.	= Os Magnum	= External Cuneiform.
Carpale (Tarsale), iv. and Carpale (Tarsale), v.	= Unciform	= Cuboid.

The pisiform is omitted from the above table, since it is now generally regarded as being a vestige of an additional digit placed post-axial to the little finger (digitus post-minimus). Its homologue in the foot is by some considered as fused with the os calcis. Similarly, on the pre-axial border of the hand and foot, vestiges of a suppressed digit (prepollex and prehallux) may

occasionally be met with. The frequent occurrence of an increase in the number of digits seems to indicate that phylogenetically the number of digits was greater than at present, and included a prepollex or prehallux, and a digitus post-minimus. The correspondence of the metacarpus with the metatarsus and the phalanges of the fingers with those of the toes is so obvious that it is sufficient merely to mention it.

The differences in size, form, and disposition of the skeletal elements of the hand and foot is easily accounted for by a reference to the functions they subserve.

In the hand strength is sacrificed to mobility, thus leading to a reduction in the size of the carpal elements, and a marked increase in the length of the digital phalanges. The freedom of movement of the thumb, and its opposability to the other digits, greatly enhances the value of the hand as a grasping organ. In the foot, where stability is the main requirement, the tarsus is of much greater proportionate size, whilst the phalanges are correspondingly reduced. Since the foot no longer serves as a grasping organ, the great toe is not free and opposable like the thumb.

Limb Girdles.—The free limbs are linked to the axial skeleton by a chain of bones which constitute their girdles. The fundamental form of these limb girdles consists each of a pair of carved cartilages placed at right angles to the axis of the trunk on either side, and embedded within its musculature. Each cartilage has an articular surface externally, about the middle, for the reception of the cartilage of the first segment of the free limb. In this way each pectoral and pelvic cartilage is divided into an upper or dorsal half and a lower or ventral half. The dorsal halves constitute the scapula and ilium of the pectoral and pelvic girdles respectively. With regard to the ventral halves there is more difficulty in establishing their homologies. The original condition is best displayed in the pelvic girdle; here the ventral segment divides into two branches—one anterior, which represents the pubis, the other posterior, which ultimately forms the ischium. Ventrally, the extremities of these cartilages unite to enclose the obturator foramen. In the pectoral girdle the disposition of the ventral cartilages is not so clear, consisting primitively of an anterior branch or precoracoid, and a posterior portion or coracoid; these, in higher forms, have undergone great modifications in adaptation to the requirements of the fore limbs. The posterior or coracoid element, the homologue of the ischial cartilage in the pelvic girdle, is but feebly represented in man by the coracoid process and the coraco-clavicular ligament. With regard to the homologue of the pubic element in the pectoral girdle, there is much difference of opinion; in reptiles and amphibia it corresponds most closely to the precoracoid, but it is doubtful what represents it in mammals. According to Goette and Hoffman, the clavicle is a primordial bone, and not, as suggested by Gegenbaur, of secondary or dermic origin. If this be so, it corresponds to the ventral anterior segment of the pectoral girdle, and is therefore homologous with the ventral anterior (pubic) segment of the pelvic girdle. On the other hand, if Gegenbaur's view be accepted, the clavicle has no representative in the pelvic girdle. It must, however, be borne in mind that during its ossification it is intimately associated with cartilage, and that that cartilage may represent the precoracoid bar; nor must too great stress be laid upon the fact that the clavicle begins to ossify before it is performed in cartilage, since that may be merely a modification in its histogenetic development.

According to another view (Sabatier), the subcoracoid centre (see Ossification of Scapula) is derived from the posterior ventral segment, and corresponds to the ischium, whilst the coracoid process is the remains of the anterior ventral segment (precoracoid), and is homodynamous with the pubis.

In no part of the skeleton does function react so much on structure as in the arrangement of the constituent parts of the pectoral or pelvic girdles. In man, owing to the assumption of the erect position and the pipedal mode of progression, the pelvic girdle acquires those characteristics which are essentially human, viz. its great relative breadth and the expansion of its iliac portions, which serve as a support to the abdominal viscera, and also furnish an extensive origin to the powerful muscles which control the movements of the hip-joint. The stability of the pelvic girdle is insured by the nature of its union with the axial skeleton, as well as by the osseous fusion of its several parts, and their union in front at the symphysis pubis.

In man, since the erection of the figure no longer necessitates the use of the fore limb as a means of support, the shoulder girdle has become modified along lines which enhance its mobility and determine its utility in association with a prehensile limb. Some of its parts remain independent (clavicle and scapula), and are united by diarthrodial joints, whilst others have become much reduced in size or suppressed (coracoid-precoracoid, see *ante*). The dorsal part of the girdle (scapula) is not directly united with the axial skeleton as is the ilium, but is only indirectly joined to it through the medium of the clavicle, which is linked in front with the presternum. The same underlying principles determine the differences in mobility and strength between the shoulder, elbow, and wrist, and the hip, knee, and ankle joints of the fore and hind limbs respectively, whilst the utility of the hand is further enhanced by the movements of pronation and supination which occur between the bones of the forearm. In the leg such movements are absent, as they would interfere with the stability of the limb.

THE ARTICULATIONS OR JOINTS.

ARTHROLOGY.

By David Hepburn.

Arthrology is that branch of human anatomy which treats of the articulations or joints.

An articulation or joint constitutes a mode of union or connexion subsisting between any two separate segments or parts of the skeleton, whether osseous or cartilaginous, and having for its primary object either the preservation of a more or less rigid continuity of the parts joined together, or else to permit of a variable degree of mobility, subject to the restraints of the uniting media.

Classification of Joints.—In attempting to frame a classification of the numerous joints in the body, several considerations must be taken into account, viz. the manner and sequence of their appearance in the embryo; the nature of the uniting media in the adult, and also the degree and kind of movement permitted in those joints where movement is possible.

In this way we obtain two main subdivisions of joints:—

(1) Those in which the uniting medium is coextensive with the opposed surfaces of the bones entering into the articulation, and in which a direct union of these surfaces is thereby effected.

(2) Those in which the uniting medium has undergone more or less of interruption in its structural continuity, and in which a cavity of greater or less extent is thus formed in the interior of the joint.

To the first group belong all the immovable joints, many of which are likewise of temporary duration; to the second group belong all joints which possess as their outstanding features mobility and permanence.

SYNARTHROSES.

The general characteristics of this group are partly positive and partly negative. Thus there is uninterrupted union between the opposed surfaces of the bones joined together at the plane of the articulation, *i.e.* there is no trace of a joint cavity, and further, there is an entire absence of movement. Developmentally, these joints result from the approximation of ossific processes which have commenced from separate centres of ossification, and therefore the nature of the uniting medium varies according as the bones thus joined together have originally ossified in membrane or in cartilage. In the former case union is effected by an interposed fibrous membrane continuous with and corresponding to the periosteum. To such articulations the term **suture** (Fig. 203) is applied. In the latter case the uniting medium is a plate of hyaline cartilage. Such articulations are called **synchondroses** (Fig. 204). In all the synchondroses, and in many of the sutures, the uniting medium tends to disappear in the progress of

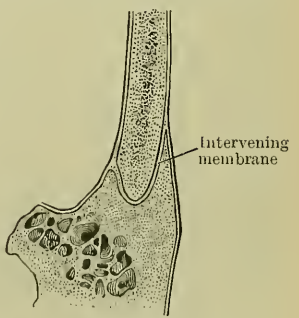


Fig. 203.—Vertical Section through a Suture.

ossification, and thus the plane of articulation becomes obliterated, so that direct structural continuity between the osseous segments takes place. The primary features common to all synarthroses are—(*a*) continuous and direct union of the opposing surfaces; (*b*) no joint cavity; (*c*) no movement.

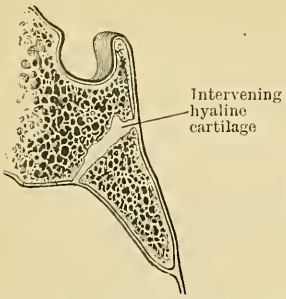


Fig. 204.—Section through the Occipito-sphenoid Synchondrosis.

Suture.—This form of synarthrosis is only found in connexion with the bones of the skull. In a large number of cases the bones which articulate by suture present irregular interlocking margins, between which there is the interposed fibrous membrane to which reference has already been made. When these interlocking margins present well-defined projections they are said to form true sutures—**sutura vera**; on the other hand, when the opposed surfaces present ill-defined projections, or even flat areas, they are described as false sutures—**sutura notha.** In each of these subdivisions the particular characters of the articulating margins are utilised in framing additional descriptive terms. Thus true sutures may possess interlocking margins whose projections are tooth-like (sutura dentata), *e.g.* in the interparietal suture; saw-like (sutura serrata), (Fig. 205) *e.g.* in the interfrontal suture; ridge-like, or comparable to the parallel ridges on the welt of a boot (sutura limbosa). Similarly false sutures may articulate by margins which are scale-like (sutura squamosa), *e.g.* in the squamoso-parietal suture; or by rough opposed surfaces (sutura harmonia), *e.g.* in the suture between the palate plates of the superior maxillary bones. There is one variety of synarthrosis which, in the adult, can scarcely be called a suture, although the differences are of minor importance, viz. **schindylesis**, which is an articulation between the edge of a plate-like bone, such as the rostrum of the sphenoid, and the cleft in another, such as the vomer.

Fig. 205.—Sutura Serrata.

Synchondrosis.—Illustrations of this group can only be found in the young growing individual, because as age advances and growth ceases, the process of ossification affects the hyaline cartilage which constitutes the uniting medium, and the plane of articulation disappears. Under this heading we may include the planes of junction between all epiphyses and the shafts or diaphyses to which they severally belong. The occipito-sphenoid (Fig. 204) and the petro-jugular articulations in the base of the skull provide other well-marked examples.

MOVABLE JOINTS.

The leading features of this group are capability of **movement** and **permanence.** In very few instances do such joints ever become obliterated under normal conditions. Determining their permanence, and regulating the amount of possible movement, there is always more or less of interruption in the continuity of the structures which bind the osseous elements together. That is, there is always some evidence of a joint cavity, although as a matter of course such interruption can never be so extensive as to entirely disassociate the articulating elements. Therefore in all movable joints a new class of structures is found, viz. the **ligaments**, by means of which continuity is maintained even when all the other uniting media have given place to a joint cavity. The further subdivision of this group is founded upon the amount of movement permissible, and the extent to which the joint cavity takes the place of the original continuous uniting medium. Thus we obtain the partly movable or **amphiarthroses**, and the freely movable or **diarthroses.**

An **amphiarthrosis** (Fig. 208) presents the following characteristics: (*a*) partial movement; (*b*) union by ligaments and by an interposed plate or disc of fibro-cartilage, in the interior of which there is, (*c*) an incomplete or partial joint cavity which may be lined by a rudimentary synovial membrane whose function it is to secrete a lubricating fluid, the **synovia** or joint-oil; (*d*) a plate of hyaline

cartilage coating each of the opposing surfaces of the bones concerned. All the joints belonging to this group occur in the mesial plane of the body. It includes the symphysis pubis, the joints between the bodies of the vertebræ, and the joint between the manubrium sterni and the gladiolus.

A **diarthrosis** (Fig. 206) is the most elaborate as well as the most complete form of articulation. It is characterised by (*a*) capability of movement which is more or less free in its range; (*b*) a reduction of the uniting structures to a series of retaining ligaments; (*c*) a joint cavity which is only limited by the surrounding ligaments; (*d*) the constant presence of **synovial membrane**; (*e*) hyaline encrusting cartilage which clothes the opposed surfaces of the articulating bones. The majority of the joints in the adult belongs to this group. This series of joints has been subdivided into a number of minor sections, in order to emphasise the occurrence of certain well-marked structural features, or because of the particular nature of the movement by which they are characterised. Although in all diarthroses there is a certain amount of *gliding* movement between the opposed surfaces of the bones which enter into their formation, yet, when this gliding movement becomes their prominent feature, as in most of the joints of the carpus and tarsus, they are termed **arthrodia**. But bones may be articulated together so as to permit of movement in one, two, or more fixed axes of movement, or in modifications of these axes. Thus in **uniaxial joints** the axis of movement may lie in the longitudinal axis of the joint, in which case the **rotatory form** of joint results, as in the superior and inferior radio-ulnar articulations; or it may correspond with the transverse axis of the articulation, as in the elbow-joint and knee-joint, when the **ginglymus** or **hinge variety** results. If movement takes place about two principal axes situated at right angles to each other, as in the radio-carpal joint, the terms **biaxial** or **condyloid** are applied. Movements occurring about three principal axes placed at right angles to each other, or in modifications of these positions, constitute **multiaxial joints**, in which the associated structural peculiarities provide the alternative terms of **enarthrodial** or **ball-and-socket joints**.

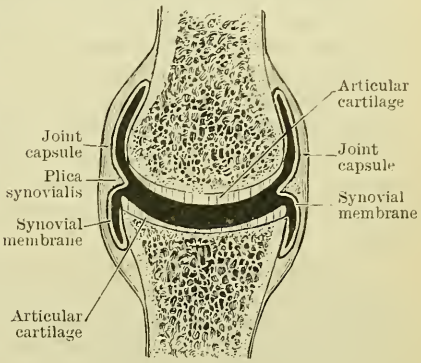


Fig. 206.—Diagram of a Diarthrodial Joint.

STRUCTURES WHICH ENTER INTO THE FORMATION OF JOINTS.

The structures which enter into the formation of joints vary with the nature of the articulation. In every instance there are two or more skeletal elements, whether bones or cartilages, and in addition there are the uniting media, which are either simple or elaborate according to the provision made for rendering the joint more or less rigid or capable of movement. We have already seen that the uniting medium in **synarthrodial joints** is a remnant of the common matrix, whether fibro-vascular membrane or hyaline cartilage, in which ossification has extended from separate centres. Among the **amphiarthroses** there is still extensive union between the opposing surfaces of the articulating bones, but the character of the uniting medium has advanced from the primitive embryonic tissue to fibrous and fibro-cartilaginous material, as well as hyaline cartilage. These, with very few exceptions, are permanent, non-ossifying substances, such as may be seen between the opposing, osseous surfaces of two vertebral bodies. The joint cavity, more or less rudimentary, is confined to the centre of the fibro-cartilaginous plate, and may result from the softening or imperfect cleavage of the central tissue. It may also present rudiments of a synovial membrane.

In the **diarthrodial group** the extensive cavity has produced great interruption in the continuity of the uniting structures which originally existed between the bones forming such a joint. Ligaments have therefore additional importance in this group, for not only do they constitute the uniting media which bind the articulating bones together, but to a large extent they form the peripheral

boundary of the joint cavity, although not equally developed in all positions. Thus every diarthrodial joint possesses a fibrous or ligamentous envelope or **capsule** which is attached to the adjacent ends of the articulating bones. For special purposes, particular parts of the capsule may undergo enlargement and thickening, and so constitute strong ligamentous bands, although still forming continuous constituents of the capsule.

Within the capsule a series of intracapsular structures are present. Thus the capsule itself is always lined by a **synovial membrane**,[1] which is continued from the inner surface of the capsule to the surface of the intracapsular portion of each articulating bone. The part of the bone included within the capsule consists of a "non-articular" portion covered by synovial membrane, and an "articular" portion covered by encrusting hyaline cartilage. The latter provides the surface which comes into apposition with the corresponding area of another bone. In its general disposition the synovial membrane may be likened to a cylindrical tube open at each end. This membrane is richly supplied by a close network of vessels and nerves.

Certain diarthroses present additional intracapsular structures which may be distinguished as interarticular ligaments and interarticular fibro-cartilages.

Interarticular ligaments extend between and are attached to non-articular areas of the intracapsular portions of the articulating bones. They usually occupy the long axis of the joint, and occasionally they widen sufficiently to form partitions which divide the joint-cavity into two compartments, *e.g.* the costo-central, and certain of the chondro-sternal joints.

Interarticular fibro-cartilages or **menisci** (Fig. 207) are more or less complete partitions situated between and separating opposing articular surfaces, and when complete they divide the joint cavity into two distinct compartments. By its periphery, a meniscus is rather to be associated with the joint capsule than with the articulating bones, although its attachments may extend to non-articular areas on the latter.

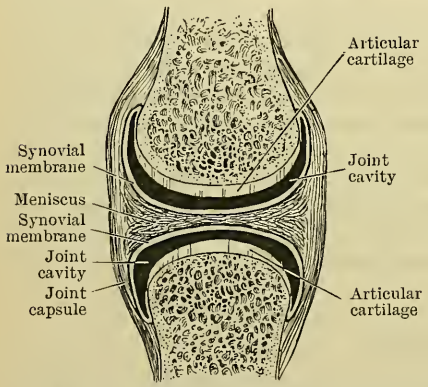


Fig. 207.—Diagram of a Diarthrodial Joint with an Interarticular Meniscus dividing the Joint-Cavity into two Compartments.

Both interarticular ligaments and menisci have their free surfaces covered by synovial membrane.

Adipose tissue forming pads of varying size is usually found in certain localities within the joint, between the synovial membrane and the surfaces which it covers. These pads are soft and pliable, and act as packing material, filling up gaps or intervals in the joint. During movement they adapt themselves to the changing conditions of the articulation.

In addition to merely binding together two or more articulating bones, ligaments perform very important functions in connexion with the different movements taking place at a joint. They do not appreciably lengthen under strains, and thus ligaments may act as inhibitory structures, and by becoming tense may restrain or check movement in certain directions.

Synovial membranes, in the form of closed sacs termed **synovial bursæ**, are frequently found in other situations besides the interior of joints. Such bursæ are developed for the purpose of reducing the friction, (*a*) between the integument and certain prominent subcutaneous bony projections, as, for instance, the point of the elbow, or the front surface of the patella (subcutaneous synovial bursæ); (*b*) between a tendon and some surface, bony or cartilaginous, over which it plays (subtendinous synovial bursæ); (*c*) between a tendon or a group of tendons and the walls of osteo-fascial tunnels, in which they play (thecal synovial bursæ). Subtendinous synovial bursæ are often placed in the neighbourhood of joints, and in such cases it not infrequently

[1] The term "synovial membrane" has been so long in use that one hesitates to discard it, even although the structure so described is not in many cases capable of being *removed* from the objects of which it forms a part. A more precise description in these cases would be "synovial surface." There is still considerable doubt whether the "synovial fluid" is a true secretion or merely a diluted friction product.

happens that there is a direct continuity between the bursa and the synovial membrane which lines the cavity of the joint through an aperture in the joint capsule.

THE DIFFERENT KINDS OF MOVEMENT AT JOINTS.

Reference has already been made to the existence of fixed axes of movement as a basis for the classification of certain forms of diarthrodial joints. Hence it is evident that the movements which are possible at any particular joint depend to a large extent upon the shape of its articular surfaces as well as upon the nature of its various ligaments. Therefore the technical terms descriptive of movements either indicate the directions in which they occur, or else the character of the completed movement.

In the great majority of articulations between short bones, the amount of movement is so restricted, and the displacement of the opposing articular surfaces so slight, that the term **gliding** sufficiently expresses its character.

A **gliding** movement of an extensive kind, for example that of the patella upon the femur, in which the movement largely resembles that of the tyre of a wheel revolving in contact with the ground so that different parts are successively adapted to each other, is called **co-aptation**.

Articulations between long bones, on the other hand, are usually associated with a much freer range of movement, with a corresponding variety in its character. **Rotation** is a movement about an axis which is longitudinal. Sometimes it is the only form of movement which a joint possesses; at other times it is merely one of a series of movements capable of execution at the same joint. **Flexion** or bending is a movement in which the formation of an angle between two parts of the body is an essential feature. As it is possible to perform this movement in relation to two axes, viz. a transverse and an antero-posterior axis, it is necessary to introduce qualifying terms. Thus, when two anterior or ventral surfaces are approximated, as at the hip-, elbow-, or wrist-joints, the movement is called **ventral**, **anterior**, or **palmar flexion**; but if posterior or dorsal surfaces be approximated by the process of bending, then the flexion becomes **posterior** or **dorsi-flexion**, as at the knee- or wrist-joints. Further, at the wrist-joint, the formation of an angle between the ulnar border of the hand and the corresponding aspect of the forearm, produces **ulnar flexion**, and similarly the bending of the hand towards the radial border of the forearm is **radial flexion**.

Extension or straightening consists in obliterating the angle which resulted from flexion. In the case of certain joints, therefore, such as the elbow, wrist, and knee, the segments of the limb occupy a straight line as regards each other when extended.

At the ankle-joint the natural attitude of the foot to the leg is flexion at a right angle. The diminution of this angle by approximating the dorsum of the foot towards the front of the leg constitutes *flexion*; while any effort at placing the foot and leg in a straight line, *i.e.* obliteration of the angle, as in pointing the toes towards the ground and raising the heel, constitutes *extension*.

Abduction is a term which either expresses movement of an entire limb, in a direction away from the mesial plane of the body, or of a digit, away from the plane of the middle finger in the hand, or the plane of the second toe in the case of the foot.

Adduction is the reverse of abduction, and signifies movement towards the mesial plane of the body, or towards the planes indicated for the digits of the hand and foot.

Circumduction is a movement peculiarly characteristic of multiaxial or ball-and-socket joints. It consists in combining such angular movements as flexion, extension, abduction, and adduction, so as to continue the one into the other, whereby the joint forms the apex of a cone of movement, and the free end of the limb travels through a circle which describes the base of this cone.

THE DEVELOPMENT OF JOINTS.

Just as the question of structure determines to a large extent the presence or absence of movement in joints, so in tracing their development it will be found that the

manner of their appearance forecasts their ultimate destination as immovable or movable articulations.

All joints arise in mesodermic tissue which has undergone more or less differentiation.

When this differentiation has produced a continuous membranous layer, in which ossific centres representing separate skeletal segments make their appearance, we get the primitive form of suture. The plane of the articulation merely indicates the limit of the ossific process extending from different directions. If, again, the differentiation of the mesoblast has resulted in the formation of a continuous cartilaginous layer, in which ossification commences at separate centres, the plane of the articulation is marked out by the unossified cartilage—in other words, the articulation is a synchondrosis. Ultimately this disappears through the extension of the process of ossification.

To some extent sutures also disappear, although their complete obliteration is not usual even in aged people. Developmentally, therefore, synarthroses or immovable joints do not present any special structural element, and, speaking generally, they have only a temporary existence.

The development of all movable joints is in marked contrast to that of synarthroses. Not only are they permanent arrangements so far as concerns normal conditions, but they never arise merely as planes which indicate the temporary phase of an ossific process. From the outset they present distinct skeletal units, from which the special structures of the joint are derived.

The primitive movable joint is first recognised as a mass of undifferentiated mesodermic cells situated between two masses, which have differentiated into primitive cartilage.

The cell-mass which constitutes the joint-unit presents the appearance of a thick cellular disc, the proximal and distal surfaces of which are in accurate apposition with the primitive cartilages, while its circumference is defined from the surrounding mesoderm by a somewhat closer aggregation of the cells of which the disc is composed. From this cellular disc or joint-unit all the structures characteristic of amphiarthrodial and diarthrodial joints are ultimately developed.

Thus by the transformation of the circumferential cells into fibrous tissue the investing ligaments are produced. Within the substance of the disc itself a transverse cleft, more or less well-defined and complete, makes its appearance. In this manner the disc is divided into proximal and distal segments, separated from each other by an interval which is the primitive joint cavity. This cleft, however, never extends so far as to interrupt the continuity of the circumferential part of the disc which develops into the fibrous tissue of the investing ligaments. From the proximal and distal segments of the articular disc the various structures, distinctive of movable joints, are developed.

Thus, in amphiarthrodial joints the cellular articular disc or primitive joint-unit gives origin to the following structures:—From its circumference, investing ligaments; from its interior, the fibro-cartilaginous plate or disc in which an imperfect joint cavity with corresponding imperfect synovial may be found.

In the case of a diarthrodial joint the changes take place on a more extended scale. The joint cavity becomes a prominent feature, in relation to which the surrounding fibrous structures form an investing capsule, lined by a synovial membrane.

When a single cleft arises, but does not extend completely across the longitudinal axis of the articular disc, the undivided portion develops into fibrous interarticular ligaments. On the other hand, when two transverse clefts are formed, that portion of the cellular disc which remains between them becomes transformed into a fibro-cartilaginous interarticular disc or meniscus, which in its turn may either be complete or incomplete, and thus we may obtain two distinct synovial joint cavities belonging to one articulation.[1]

In considering the development of the synovial membrane, and the surfaces on which it is found in the interior of a joint, it is necessary to keep clearly in mind that a synovial membrane is a special structure, whose function it is to produce a lubricating fluid or synovia, and that, therefore, its position is determined by the essential necessity of proximity to a direct blood-supply. In other words, this condition is provided by all parts of the interior of a joint cavity except the articular encrusting cartilage. Consequently synovial membrane is only absent from the free surface of articular cartilage, although it forms a thicker layer upon the inner surface of the joint capsule than upon the free surfaces of interarticular ligaments and menisci.

[1] From a series of observations upon the development of diarthrodial joints, the writer considers that there is evidence to show that the "cellular articular disc" is directly responsible for the production of the epiphyses which adjoin the completed joint cavity, and that, among such amphiarthroses as exist between the bodies of vertebræ, not only the intervertebral disc, but the proximal and distal epiphyses which ultimately unite with the vertebral bodies have a common origin in the joint-unit.

It is not necessary to suppose that the synovial membrane has disappeared from these articular cartilages as the result of friction, because, notwithstanding constant friction, such parts as the interior of capsular ligaments or the semilunar cartilages of the knee-joint have not been denuded of their synovial covering.

MORPHOLOGY OF LIGAMENTS.

From what has been said in connexion with the development of joints, it will be evident that ligaments are essentially products derived from the cellular articular disc.

Nevertheless, in relation to the fully-formed joint, many structures are described as ligaments which do not take origin in the manner just indicated. Some of these ligamentous structures remain fairly distinct from the capsular ligaments with which they are immediately associated; others become thoroughly incorporated with the capsular ligaments and cannot be separated therefrom, while yet others may be found situated within the capsule of a joint, and thus play the part of interarticular ligaments.

Instances of each of these forms of adventitious ligaments may be readily given. For example, we may instance the expansion of the tendon of the semimembranosus muscle to the posterior ligament of the knee-joint, and the offshoots from the tendon of the tibialis posticus muscle to the plantar aspects of various tarsal bones, as illustrations of structures which play an important part as ligaments, but are not indelibly incorporated with the joint capsule.

Of structures which have become indelibly incorporated with the primitive capsule, we may instance the broad tendinous expansions of the quadriceps extensor muscle around the knee-joint.

The internal lateral ligament of the same joint is regarded as a detached portion of the tendon belonging to that part of the adductor magnus muscle which takes origin from the ischium, while the external lateral ligament of the knee is considered by some to be the primitive femoral origin of the peroneus longus muscle. Another illustration of the same condition is found in the coraco-humeral ligament, which is regarded by some as representing a detached portion of the pectoralis minor muscle.

Two illustrations may be given of structures playing the part of ligaments within the capsule of a joint, although in the first instance they are not developed as ligaments. It is questionable if the ligamentum teres of the hip-joint is an interarticular ligament in the true sense of the term; it has been regarded as the isolated and displaced tendon of the ambiens muscle found in birds. In the shoulder-joint, many observers look upon the superior gleno-humeral ligament as representative of the ligamentum teres.

Such structures as the stylohyoid ligament and the internal lateral ligament of the temporo-mandibular joint, although described as ligaments, are in reality skeletal parts which have not attained their complete ossific development.

Again, certain portions of the deep or muscular fascia of the body which become specialised into restraining and supporting bands (*e.g.* the ilio-tibial band of the fascia lata; the stylo-mandibular ligament; the anterior and posterior annular ligaments of the wrist-joint; the anterior, inner, and outer annular ligaments of the ankle-joint), although called ligaments, have no direct developmental association with articular ligaments.

Lastly, the ligament of Poupart and the ligament of Gimbernat, being special developments in connexion with an expanded tendon or aponeurosis, are still further removed from association with an articulation.

LIGAMENTS OF THE VERTEBRAL COLUMN AND SKULL.

All vertebræ, with the exception of those which deviate from the common vertebral type, present two sets of articulations whose various parts are arranged upon a uniform pattern. Thus every pair of typical vertebræ presents an articulation between the centra, termed **intercentral**, and a pair of articulations between the neural arches, called **interneural**. With the latter there are associated various important accessory ligaments which bind together laminæ, spinous processes, and transverse processes.

Intercentral Articulations.—These are amphiarthrodial joints. Singly, they present only a slight degree of mobility, but when this amount of movement is added to that of the whole series, the range of movement of the spine becomes considerable. The articular surfaces are the flattened surfaces of adjacent vertebral bodies. They are bound together by the following structures:—

Intervertebral Discs (fibro-cartilagines intervertebrales, Fig. 208).—Each disc accommodates itself to the space it occupies between the two vertebral bodies, to both of which it is firmly adherent. The discs, from different parts of the spinal column, vary in vertical thickness, being thinnest from the third to the seventh dorsal vertebra, and thickest in the lumbar region. In the cervical and lumbar regions each disc is thicker in front than behind, thereby assisting in the production of the

anterior convexity which characterises the spinal column in these two regions. In the dorsal region the discs are thinnest on their anterior aspects in correspondence with the anterior concavity of this section of the spine.

Each disc consists of a circumferential portion (annulus fibrosus), formed for

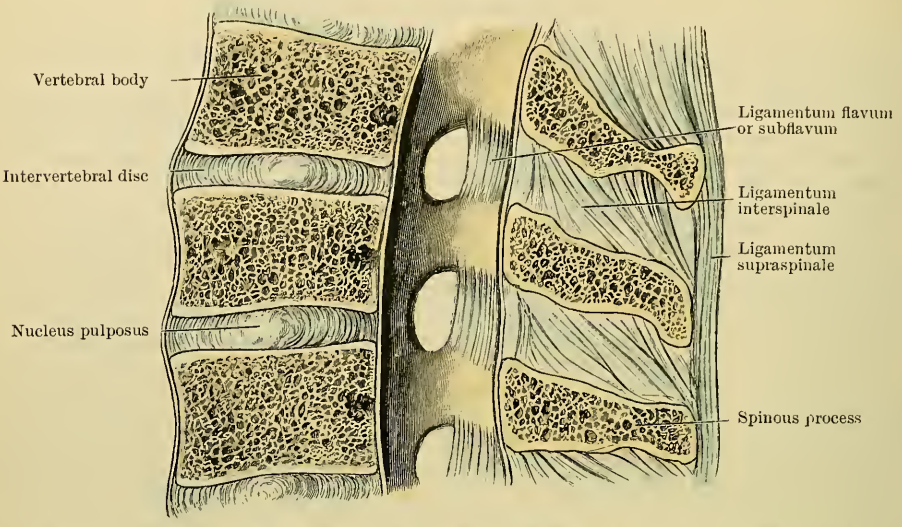


Fig. 208.—Mesial Section through a Portion of the Lumbar Part of the Spine.

the most part of oblique parallel fibres running from one vertebra to the other. Horizontal fibres are also found. The axial or central part of the disc is elastic, soft, and pulpy (nucleus pulposus).[1]

The upper and lower surfaces of the disc are closely adherent to the adjoining

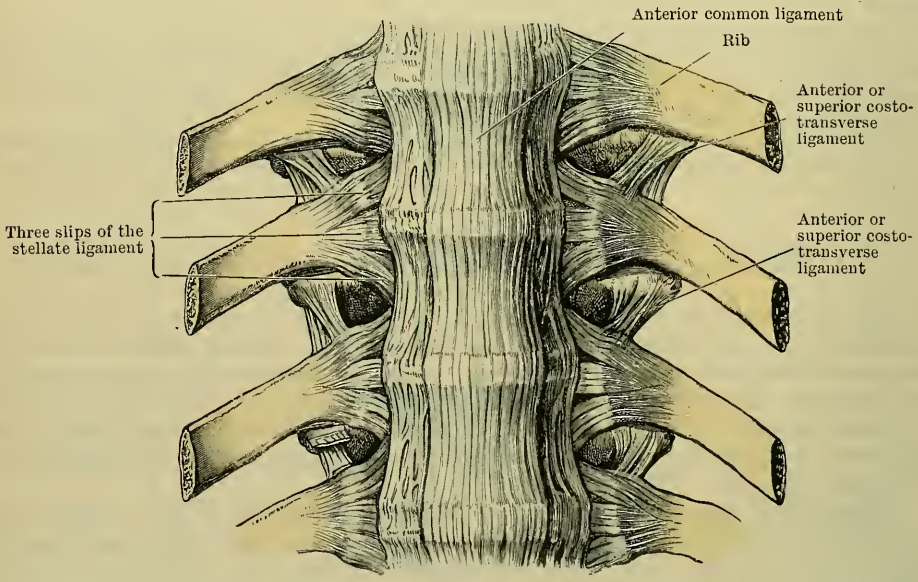


Fig. 209.—Anterior Common Ligament of the Vertebral Column, and the Costo-vertebral Joints as seen from the Front.

epiphyseal plates of the vertebral bodies, and as ossification advances, the distinction between epiphyseal plates and vertebral body disappears.

As a rule the transverse diameter of the disc corresponds to that of the vertebral bodies which it joins together; but in the cervical region, where the lower

[1] This pulpy substance does not present a joint cavity, but in certain cases it is more or less divided by fissures which occupy a transverse horizontal direction.

margin of the superimposed vertebra is overlapped on each side by the one which bears it, the disc does not extend to the extreme lateral margin, and in this position a small diarthrosis may be seen at each lateral margin of the disc.

The **anterior common ligament** (lig. longitudinale anterius, Fig. 209) consists of a wide stratum of longitudinal fibres which extends from the front of the axis vertebra to the front of the upper segment of the sacrum, and becomes gradually wider from above downwards. It lies in front of the intervertebral discs, to which it is firmly attached as it passes from one vertebra to the other. Its fibres vary in length. Some are attached to contiguous margins of two adjoining vertebræ; others pass in front of one vertebra to be attached to the next below, and yet others find their lower attachment three or four vertebræ below the one from which they started. None of the fibres are attached to the transverse depression on the front of a vertebral body.

The **posterior common ligament** (lig. longitudinale posterius, Fig. 210) is found within the spinal canal upon the posterior aspect of the vertebral bodies. It consists of longitudinal fibres, and it extends from the back of the sacrum to the axis vertebra, superior to which it is continued to the skull as the posterior occipito-axial ligament. Opposite each intervertebral disc it is attached to the entire width of the adjacent margins of the two vertebral bodies, its fibres being continued over the posterior surface of the disc. In the lumbar and dorsal regions the width of the ligament is considerably reduced opposite the back of each vertebral body, and thus it forms a series of dentate projections along both of its margins; but in the cervical region the width of the ligament is more uniform.

One or two large thin-walled veins escape from the body of each vertebra under cover of this ligament.

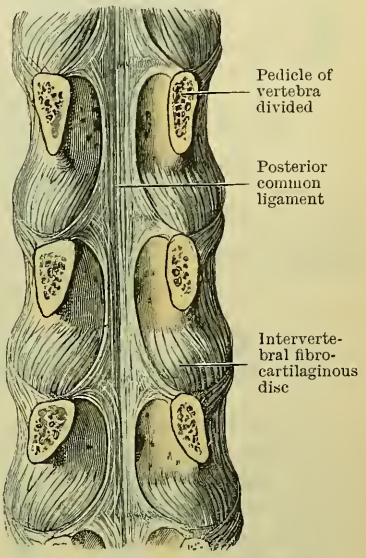


Fig. 210.—Posterior Common Ligament of the Vertebral Column.

Interneural Articulations.—The neural arch of each typical vertebra carries two pairs of articular processes, by means of which it articulates with adjacent neural arches. The articulations between these processes are true diarthroses of the arthrodial variety.

The distinctive characters of these articular surfaces, as regards their shape and direction in the different groups of vertebræ, have been referred to in the section on osteology.

All these articulations are provided with complete but very thin-walled **capsules** (capsulæ articulares), which are thinnest and loosest in the cervical region, where also the movements are freest. Each capsule is lined by a **synovial membrane.**

Associated with these interneural joints are certain ligaments which are accessory to the articulations, although they are quite distinct from the capsule.

The laminæ of adjoining vertebræ are bound together by the **ligamenta subflava** (ligamenta flava vel subflava, Fig. 211), which consist of yellow elastic fibres. The ligamenta subflava close the spinal canal in the intervals between the laminæ. Each ligament is attached superiorly to the anterior aspect of one lamina at a short distance above its lower border, and inferiorly it is attached to the posterior aspect of the subjacent lamina.

In the dorsal region, where the imbrication of adjoining laminæ is a prominent feature, these ligaments are not so distinctly visible from behind as they are in the regions where imbrication of the laminæ is not so marked.

Laterally they extend as far as the articular capsules, while mesially the margins of the ligaments of opposite sides meet under cover of the root of the spinous process.

Contiguous pairs of spinous processes are also attached to each other by **interspinous ligaments** (ligamenta interspinalia, Fig. 208). These are strongest in the

lumbar, and weakest in the dorsal region. Each consists of layers of obliquely interlacing fibres which spring from near the tips of the two adjacent spines and radiate to their opposing margins. In the antero-posterior direction they extend from the base to the tip of the spinous process.

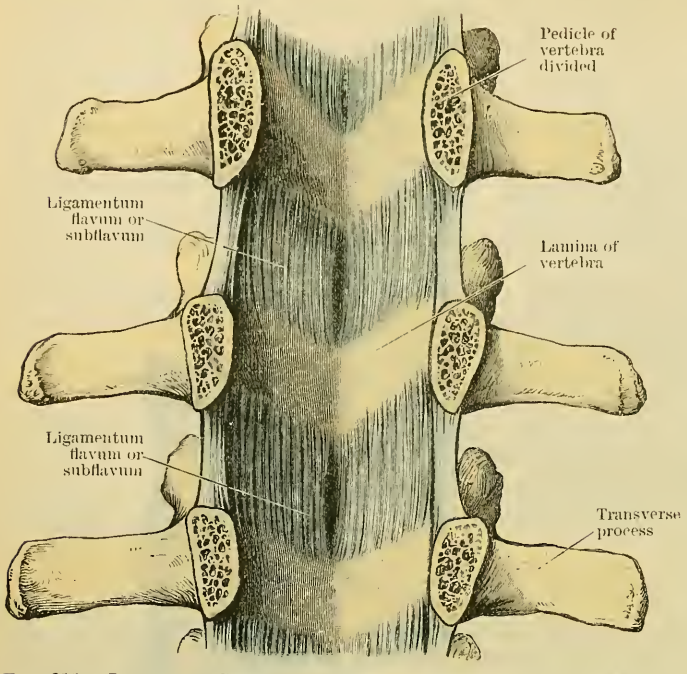


FIG. 211.—LIGAMENTA SUBFLAVA AS SEEN FROM THE FRONT AFTER REMOVAL OF THE BODIES OF THE VERTEBRÆ BY SAWING THROUGH THE PEDICLES.

The **supraspinous ligaments** (ligg. supraspinalia, Fig. 208) consist of longitudinal bands of fibres of varying lengths. They extend from spine to spine, being attached to their tips, and are situated superficial to, although in continuity with, the interspinous ligaments.

In the cervical region this series of ligaments is extensively developed, where they project backwards from the spinous processes between the muscles of the two sides of the neck in the form of an elastic partition called the **ligamentum nuchæ**.

The antero-posterior extent of the ligamentum nuchæ increases as it approaches the occiput, where it is attached to the occipital crest from the external occipital protuberance to the posterior border of the foramen magnum. Its posterior margin is free, and extends from the external occipital protuberance to the spine of the vertebra prominens.

Between the transverse processes there are **intertransverse ligaments** (ligg. intertransversaria), which consist of vertical fibres extending from the postero-inferior aspect of one transverse process to the superior margin of that next below. These ligaments are generally absent from the cervical and upper dorsal regions.

Sacro-coccygeal Joint.—The last piece of the sacrum is joined to the first piece of the coccyx by an intervertebral disc, and the junction is rendered more secure by the presence of certain strong ligaments. An **anterior ligament** (lig. sacro-coccygeum anterius), continuous with the anterior common ligament, is placed in front. A **posterior ligament** (lig. sacro-coccygeum posterius), which stretches downwards from the sharp border of the lower opening of the sacral canal, strengthens the joint behind. A **lateral ligament** (lig. sacro-coccygeum laterale) supports the joint on each side, whilst strong bands pass between the cornua of the two bones and constitute the **interarticular ligaments**.

Inter-coccygeal Joints.—So long as they remain separate, the different pieces of the coccyx are joined by intervertebral discs and by anterior and posterior ligaments.

Movements of the Vertebral Column.—Although the amount of movement permissible between any two vertebræ is extremely limited, yet the total range of movement capable of being attained by the entire vertebral column is very considerable.

Flexion may occur both forwards and backwards at the intercentral articulations, but more freely in the lumbar and cervical regions than in the dorsal region, where the limited amount of intervertebral disc and the imbrication of the laminæ and spines restrict the movement. Backward flexion is most pronounced in the cervical region, and forward flexion in the lumbar region. Between the articular surfaces of the interneural articulations a variety of movements are permitted, dependent upon the directions of these surfaces. Thus **lateral flexion** is permitted in

the lumbar, but not in the cervical or dorsal regions. Again, in the lumbar region **rotation** does not occur, owing to the shape of the articular processes, while it is possible in the dorsal region. In the cervical region the shape and position of the articular surfaces prevent the occurrence both of lateral flexion and of rotation as isolated movements, but a combination of these two movements may take place, whereby rotatory movement in an oblique median axis results. Finally, in the lumbar region, by combining the four forms of flexion, viz. forward, backward, and lateral, a certain amount of **circumduction** is possible.

Articulation of Atlas with Axis.

Between these two vertebræ three diarthroses occur. Two of them are situated laterally in relation to the articular processes, and are called arthrodial diarthroses, because of the flattened nature of the articulating surfaces. The third articulation is mesial in position. It is found between the smooth anterior surface of the odontoid process of the axis and the articular facet on the posterior aspect of the anterior arch of the atlas. This joint is a rotatory diarthrosis.

Ligaments.—Each of the joints is furnished with a **capsular ligament** whereby

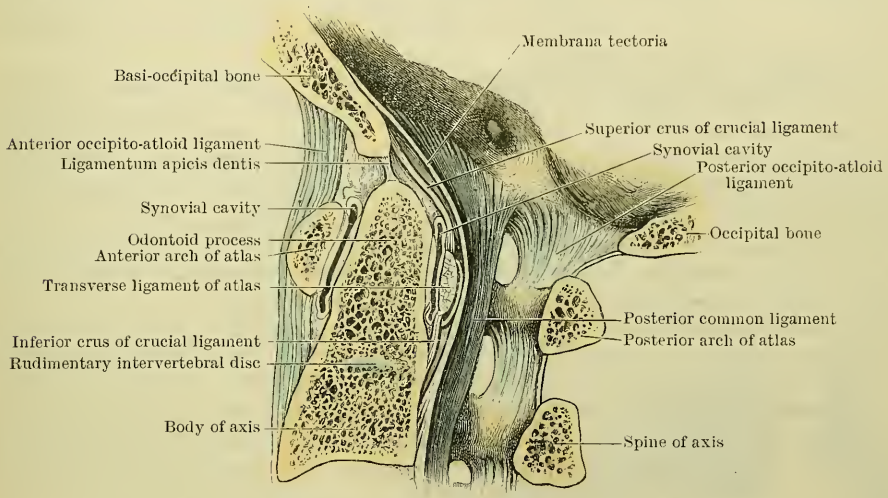


Fig. 212.—Mesial Section through the Occipito-atloid and Atlo-axoid Joints.

the joint cavity is circumscribed. In the case of the lateral articulations, each capsular ligament presents a distinct band, named the **accessory ligament**, which is situated within the neural canal (Fig. 213), and passes downwards and inwards from the lateral mass of the atlas to the superior aspect of the body of the axis.

The following additional ligaments constitute the leading bonds of union :—

The **anterior atlo-axoid ligament** (Fig. 212) is a membranous structure which is thin laterally, but strong mesially where it is thickened by a prolongation of the anterior common ligament. It extends from the anterior arch of the atlas to the front of the body of the axis.

The **posterior atlo-axoid ligament** (Fig. 212) occupies the position which is elsewhere taken by the ligamenta subflava. It extends from the posterior arch of the atlas to the upper border of the neural arch of the axis.

The **transverse ligament of the atlas** (lig. transversum atlantis, Figs. 212 and 213) is a strong band, placed transversely, which arches backwards behind the neck of the odontoid process of the axis. By its extremities it is attached to the tubercle on the inner aspect of each lateral mass of the atlas. A thin plate of fibro-cartilage is developed in its central part.

Synovial membrane lines each of the three capsular ligaments, and in addition a synovial sac is developed between the odontoid process and the transverse ligament. This is more extensive than the synovial cavity between the odontoid process and the atlas.

Articulation of Spine with Cranium.

There are two articulations between the atlas and the occiput. Each is a diarthrosis in which movement takes place in relation to two axes, viz. the transverse and the antero-posterior. The condyle of the occiput being biconvex, fits into the biconcave superior articular surface of the atlas, while the long axes of the two joints are directed horizontally forwards and inwards.

Ligaments.—Each articulation is provided with a **capsular ligament** which is thin but complete. It is attached to the rough non-articular surfaces surrounding the articular areas on the atlas and occiput.

The following supplementary ligaments are the chief structures which bind the atlas to the occiput:—

The **anterior occipito-atloid ligament** (membrana atlanto-occipitalis anterior, Fig. 212) is a strong although thin membrane, attached inferiorly to the anterior arch of the atlas, and superiorly to the anterior half of the circumference of the foramen magnum. Laterally it is in continuity with the capsular ligaments, while in the mesial plane, where it extends from the anterior tubercle of the atlas to the basi-occiput, it presents a specially well-defined thickened band which might be regarded as a separate accessory ligament or as the beginning of the anterior common ligament of the vertebræ.

The **posterior occipito-atloid ligament** (membrana atlanto-occipitalis posterior, Fig. 212) is another distinct but still thin membrane which is attached superiorly to the posterior half of the circumference of the foramen magnum, and inferiorly to the upper border of the posterior arch of the atlas. Laterally it also is continuous with the capsular ligaments. On each side of the mesial plane its inferior border is arched in relation to the vertebral groove, and is therefore to some extent free, in order to permit the passage of the posterior primary division of the first cervical nerve and the vertebral artery. Not infrequently this arched border becomes ossified, thus converting the groove in the bone into a foramen.

Synovial membrane lines each of the capsular ligaments. There is no direct articulation between the axis and the occiput, but union between them is effected by means of the following accessory ligaments:—

The **posterior occipito-axoid ligament** (membrana tectoria, Fig. 213) is situated within the neural canal, and is usually regarded as the upward continuation of the posterior common ligament of the vertebral bodies. It extends from the posterior

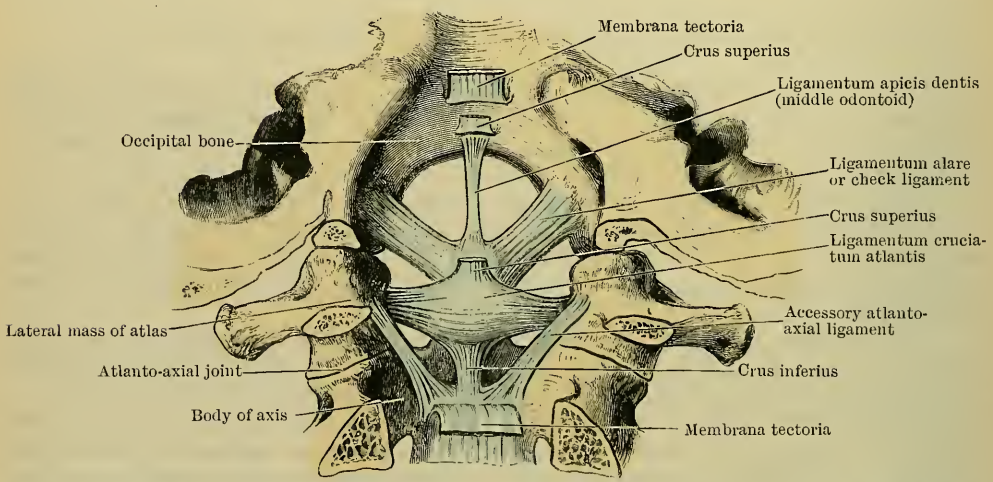


Fig. 213.—Dissection from behind of the Ligaments connecting the Occipital Bone, the Atlas, and the Axis with each other.

surface of the body of the axis to the basilar groove on the upper surface of the basi-occipital bone, spreading laterally on the circumference of the foramen magnum. Some of its deepest fibres are attached to the atlas immediately above the atlo-axoid articulation.

Subjacent to the preceding ligament there is the **ligamentum cruciatum atlantis** (Fig. 213), a structure which is very closely associated with the lig. transversum atlantis. It consists of a *crus transversum*, formed by the superficial fibres of the transverse ligament of the atlas; a *crus inferius*, consisting of mesial longitudinal fibres which are attached below to the posterior surface of the body of the axis, and above to the crus transversum and a *crus superius*, also mesial and longitudinal, whose fibres extend from the crus transversum upwards to the posterior surface of the basi-occiput, immediately subjacent to the posterior occipito-axoid ligament.

The **check ligaments** or **lateral odontoid ligaments** (ligamenta alaria, Fig. 213) are two very powerful, short, and somewhat rounded bands. They are attached mesially to the sides of the summit of the odontoid process, and laterally to the tubercle on the inner aspect of the condylar portions of the occipital bone, viz. the ex-occipital bones.

The **middle odontoid ligament** (ligamentum apicis dentis, Fig. 213) consists of fibres running vertically upwards from the apex of the odontoid process to the mesial part of the anterior margin of the foramen magnum. This ligament to some extent represents an intervertebral disc, in the centre of which remains of the notochord may be regarded as present.

Even in advanced life a small lenticular mass of cartilage, completely surrounded by bone, persists in the plane of fusion between the odontoid process and the body of the axis.

Movements at these Joints.—At the joints between occiput and atlas the movements are very simple, and consist essentially of movements whereby the head is elevated and depressed upon the vertebral column (nodding movements). In addition a certain amount of oblique movement is possible, during which great stability is attained by resting the front and hinder parts of opposite condyles upon corresponding parts of the atlas.

The head and the atlas rotate together upon the axis, the pivot of rotation being the odontoid process, and the amount of rotation is limited by the check ligaments. No rotation can occur between the occiput and atlas, and stability between atlas and axis is best attained after a slight amount of rotation, similar to the oblique movement between occiput and atlas.

TEMPORO-MANDIBULAR JOINT.

This joint is an arthrodial **diarthrosis**. It occurs between the articular part of the glenoid fossa of the temporal bone and the condylar head of the mandible. These two articular surfaces are markedly dissimilar both in size and shape. In its general outline the articular surface of the head of the mandible is cylindrical, having its long axis directed from within outwards and forwards. On the other hand, the articular part of the glenoid fossa in front of the Glaserian fissure is concavo-convex from behind forwards. Its articular surface includes the eminentia articularis, the eminence at the base of the anterior root of the zygoma. The articular surfaces of the bones are clothed by hyaline encrusting cartilage, whilst the joint cavity is divided into an upper and lower part by a meniscus of fibro-cartilage.

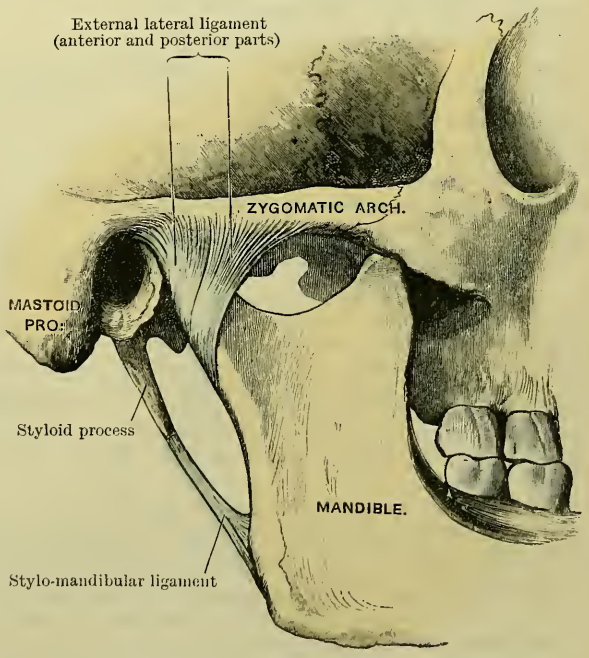


FIG. 214.—TEMPORO-MANDIBULAR JOINT.

Ligaments.—The joint is invested by a **capsular ligament** which is quite com-

plete, but is very thin on the inner side. The outer wall of the capsule—the **external lateral ligament** (lig. temporo-mandibulare, Fig. 214)—is divisible into anterior and posterior portions which are attached superiorly to the root tubercle and lower border of the zygoma, and inferiorly to the outer side and posterior border of the neck of the mandible. The direction of its fibres is downwards and backwards.

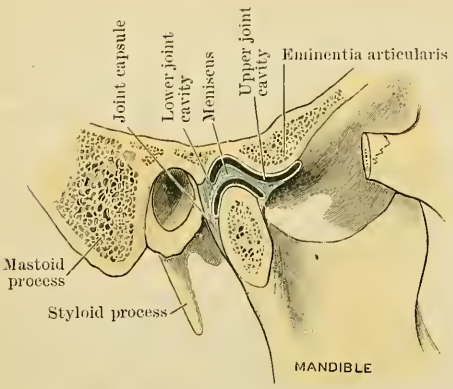


Fig. 215.—Section through the Temporo-Mandibular Joint.

Within the capsule there is an inter-articular disc or meniscus of fibro-cartilage, the **discus articularis** (Fig. 205), which is moulded upon the condyle of the mandible below, and on the articular surface of the temporal bone above. It thus compensates for the incongruity between the articular surfaces of the two bones. The disc is attached circumferentially to the capsule. It is widest in the transverse direction, thicker behind than in front, and thinnest towards the centre, where it may be perforated. Its anterior margin is intimately associated with the insertion of the external pterygoid muscle.

A **synovial membrane** lines each of the compartments into which the joint cavity is divided by the meniscus. As a rule these membranes are separate from each other, but they become continuous when the disc is perforated. The upper synovial membrane is larger and more loosely disposed than the lower.

Situated on the mesial aspect of the joint, but at a short distance from it, and quite distinct from the capsule, there is an accessory band called the **internal lateral ligament** (lig. spheno-mandibulare, Fig. 216). Superiorly it is attached to the spinous process of the great wing of the sphenoid bone, and inferiorly to the lower as well as the hinder border or lingula of the inferior dental foramen. It is not an articular ligament in the true sense, for instead of being connected with the joint, it is developed in the tissue surrounding part of Meckel's cartilage.

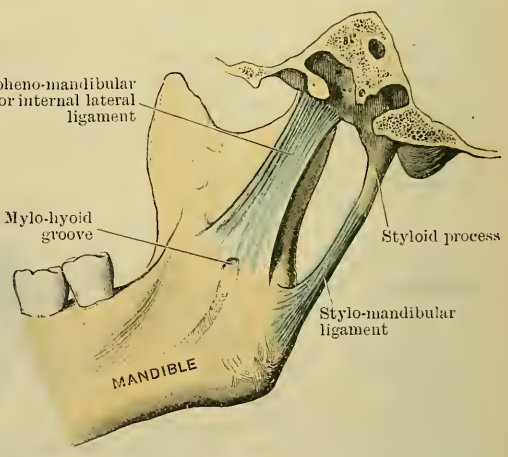


Fig. 216.—Internal Lateral Ligament of the Temporo-Maxillary Joint.

Portions of the following structures are found in the interval between the spheno-mandibular ligament and the ascending ramus of the mandible—viz. the external pterygoid muscle; internal maxillary vessels; inferior dental vessels and nerve; middle meningeal vessels; auriculo-temporal nerve; a deep portion of the parotid gland.

Movements of the Mandible.—The nature of the movements which the lower jaw can perform is determined partly by the character of the articular surfaces of the temporo-mandibular joint, and partly by the fact that, while the two joints always act simultaneously, they may also, to some extent, perform the same movement alternately.

When movement takes place through the long or transverse horizontal axis of each joint, the mandible may be elevated, as in clenching the teeth, or it may be depressed, as in gaping. In the latter movement the condyle leaves the glenoid fossa, and, along with the meniscus, it moves forwards until they rest upon the articular eminence. Meantime the chin describes the arc of a circle, of which the centre or point of least movement corresponds to the position of the inferior dental foramen, and thus the structures which enter at that foramen are protected against stretching. Coincidently with the forward movement of the condyle, it glides in a revolving manner upon the inferior aspect of the meniscus.

At any stage in the movement of depressing the chin the mandible may be protruded, so that the inferior incisor teeth are projected in front of the upper set, a movement which results from the condyles of the jaw being drawn forwards upon the articular eminences. A similar

relation of the condyle to the articular eminence occurs during the exaggerated depression of the mandible which results from yawning, in which position the articulation is liable to be dislocated. When the two joints perform the same movement alternately, a certain amount of lateral motion results, from the fact that the long axis of each joint presents a slight obliquity to the transverse axis of the skull, and consequently a grinding or oblique movement in the horizontal plane is produced. Excessive depression, with the risk of dislocation, is resisted by the fibres of the external lateral ligament which becomes tense.

In all movements of the mandible the meniscus conforms closely to the position of the condyle, and they move forwards and backwards together, but at the same time the meniscus does not restrict the movements of the condyle. Thus while the meniscus, along with the condyle, is gliding upon the temporal aspect of the joint, the condyle itself revolves upon the inferior surface of the meniscus.

Cranial Ligaments not directly associated with Articulations.

The **stylo-mandibular ligament** (lig. stylo-mandibulare, Figs. 214 and 216) is a specialised portion of the deep cervical fascia which extends from the anterior aspect of the tip of the styloid process of the temporal bone to the posterior border of the angle of the mandible, between the insertions of the masseter and internal pterygoid muscles.

The **pterygo-spinous ligament** (lig. pterygo-spinosum) is a membrane extending from the upper part of the posterior free margin of the external pterygoid plate, backwards and slightly outwards, to the spinous process of the sphenoid. An interval is left between its upper border and the floor of the skull for the outward passage of those branches of the inferior maxillary nerve which supply the external pterygoid, temporal, and masseter muscles. This ligament has a tendency to ossify either wholly or partially.

The **stylo-hyoid ligament** (lig. stylo-hyoideum) may be regarded as the downward continuation of the styloid process of the temporal bone. Inferiorly it is attached to the lesser cornu of the hyoid bone. It is not infrequently ossified, in which case it constitutes the epihyal bone found in many animals.

THE JOINTS OF THE THORAX.

Costo-vertebral articulations (articulationes costo-vertebrales). The typical rib articulates with the vertebral column both by its head and by its tubercle. Thus, two sets of articulations, with their associated ligaments, exist between the ribs and the vertebræ, but each set is constructed upon a common plan, with the exception of certain joints situated at the upper and lower ends of the series, where the ribs themselves deviate from the typical form.

Costo-Central Joints.

The articulations of the heads of the ribs with the centra or bodies of the vertebræ (articulationes capitulorum, Fig. 209) are all diarthroses, which, from their somewhat hinge-like action, may be classed as ginglymoid.

The head of every typical rib is wedge-shaped, and presents two articular facets, an upper and a lower, separated from each other by an antero-posterior ridge which abuts against an intervertebral disc, while the articular facets articulate with similar surfaces on the contiguous margins of the two vertebræ adjoining the disc. These surfaces form a wedge-shaped depression or cup, the bottom of which is more elastic than the sides, and thus an arrangement is provided which tends to reduce the shock of blows upon the walls of the chest.

Each of these articulations is provided with a **capsular ligament** which surrounds and encloses the joint, and is attached to contiguous non-articular margins on the head of the rib and the two vertebral bodies. On its anterior or ventral aspect the capsule presents three radiating fasciculi which collectively form the **stellate** or **anterior costo-vertebral ligament** (lig. capituli costæ radiatum, Fig. 209). These fasciculi radiate from a centre on the front of the head of the rib, so that the middle fasciculus becomes attached to the intervertebral disc while

the upper and lower fasciculi proceed to the adjacent margins of the two vertebræ between which the disc is situated, and with which the rib articulates. To a slight extent these radiating fasciculi pass under cover of the lateral margin of the anterior common ligament of the vertebral bodies. In those joints in which the head of the rib does not articulate with an intervertebral disc the central fasciculus of the stellate ligament is wanting, but the other two retain the same general arrangement.

The **interarticular ligament** (lig. capituli costæ interarticulare) consists of short transverse fibres within the capsule. These are attached, on the one hand, to the ridge which intervenes between the two facets on the head of the rib, and on the other to the lateral aspect of the intervertebral disc. This ligament is not a meniscus, but merely an interarticular ligament, of width sufficient to divide the joint cavity into an upper and a lower compartment. It is absent from those joints which do not articulate with an intervertebral disc, *i.e.* from those ribs which only articulate with the body of one vertebra.

The interarticular ligament is supposed to represent the outer end of a ligament which, under the name of the **lig. conjugale costarum**, connects the heads of the ribs of certain mammals across the posterior aspect of the intervertebral disc, and, in the human subject, until the seventh month of fœtal life, connects the posterior aspects of the necks of a pair of ribs with each other across the mesial plane.

Synovial membrane lines each joint cavity, and therefore, in all cases where the joint is divided into two compartments, each one has its own synovial lining.

Costo-Transverse Joints.

The tubercle of each *typical* rib articulates with the transverse process of the lower of the two dorsal vertebræ with which the head of the rib is associated (articulatio costo-transversaria). Near the tip of the transverse process there is an articular facet, on its anterior aspect, for articulation with the corresponding facet on the mesial articular part of the rib tubercle. The joint so formed is an arthrodial diarthrosis.

The joint cavity is surrounded by a comparatively feeble **capsular ligament**, which is attached immediately beyond the margins of the articular facets, and in which no special bands can be distinguished.

A simple **synovial membrane** lines the capsular ligament in all cases where the latter is present.

The following accessory ligaments, in connexion with this joint, strengthen and support the articulation :—

The **anterior** or **superior costo-transverse ligament** (ligamentum costo-transversarium anterius, Fig. 209) consists of strong bands of fibres which are attached to the upper border of the neck of the rib, extending from the head outwards to the non-articular part of the tubercle. All these fibres may be traced upwards. Those situated nearest to the head of the rib proceed obliquely upwards and outwards, to be attached to the transverse process immediately above, but with extensions to the adjoining rib and its costo-transverse capsular ligament. Others proceed almost vertically upwards to the adjoining transverse process, while those which ascend from the upper surface of the tubercle pass obliquely upwards and inwards to reach the postero-inferior aspect of the adjoining transverse process.

The **posterior costo-transverse ligament** (ligamentum costo-transversarium posterius) is a band of transverse fibres applied to the postero-external aspect of the capsule. By one end these fibres are attached to the tip of the transverse process behind its articular facet, and by the other to the external rough surface of the tubercle of the rib.

The **middle costo-transverse ligament** (lig. colli costæ) consists of short fibres which stretch from the posterior aspect of the neck of the rib, backwards and inwards, to the front of the transverse process, but, in addition, a proportion of the fibres passes to the posterior aspect of the inferior articular process of the upper of the two vertebræ with which the head of the rib articulates.

The following exceptions to the general plan of rib-articulation indicated above must be noted:—

1. There is no articulation between the eleventh and twelfth ribs and the transverse processes of the corresponding vertebræ.
2. The superior costo-transverse ligament is wanting from the first rib, and is either rudimentary or wanting in the case of the twelfth rib.
3. The middle costo-transverse ligament is rudimentary in the eleventh and twelfth ribs.

The **ligamentum lumbo-costale** extends from the upper surface of the base of the transverse process of the first lumbar vertebra to the under surface of the neck of the twelfth rib, as well as to the under surface of the transverse process of the twelfth dorsal vertebra.

Articulations between the Ribs and their Cartilages.

Each rib possesses an unossified portion, termed its costal cartilage. As age advances, this cartilage may undergo a certain amount of superficial ossification, but it never becomes entirely transformed. The line of demarcation between bone and cartilage is clear and abrupt, and usually the bone forms an oval cup, in which the end of the cartilage is retained by means of the continuity which exists between the periosteum and the perichondrium. There is no articulation in the proper sense between the rib and its cartilage, although a synovial cavity has occasionally been found between the first rib and its cartilage.

Interchondral Joints.

These articulations are arthrodial diarthroses, and they are found between adjoining margins of certain of the costal cartilages, viz. from the fifth to the eighth or ninth. The cartilages which thus articulate develop flattened, somewhat conical, prolongations of their substance, and thereby the intercostal spaces are interrupted where these flat articular facets abut against each other. Each joint is closed by a surrounding **capsular ligament**, the superficial and deep aspects of which are specially strengthened by **external** and **internal interchondral ligaments.** These bands extend obliquely between adjacent cartilages.

A **synovial membrane** lines each joint capsule.

Costo-sternal Joints.

The upper seven pairs of costal cartilages, as a rule, extend to the lateral margins of the sternum (articulationes sternocostales). Of these, the first pair is implanted directly upon the manubrium sterni. The ossific process ends abruptly in connexion with the rib, and also ceases as suddenly in connexion with the sternum, and hence the cartilage does not normally present an articulation at either end.

From the second to the seventh pairs of ribs inclusive, the costo-sternal joints are constructed upon the type of arthrodial diarthroses, although, in the case of the sixth and seventh cartilages, the joint cavity is always small, and is frequently obliterated.

The sternal end of each of these costal cartilages presents a slight antero-posterior ridge which fits into a shallow V-shaped depression upon the lateral margin of the sternum. With the exception of the sixth cartilage, the others articulate opposite the lines of union between the primary segments of the sternum, whereas the sixth articulates upon the side of the lowest segment of the meso-sternum.

Each joint is enclosed by a **capsular ligament**, composed of fibrous tissue, attached to the adjacent borders of the articulating elements. Specially strong fibres distinguish the superficial and deep aspects of the capsule.

The **anterior costo-sternal ligament** (lig. costo-sternalium radiatum, Fig. 217) is composed of strong fibres which radiate from the anterior surface of the costal cartilage, near its sternal end, to the front of the sternum. The ligaments of opposite sides interlace with each other, and so cover the front of the sternum with a felted membrane—the **membrana sterni.**

The **posterior costo-sternal ligament**—also a part of the capsule—has attachments similar to the foregoing, but the arrangement of its fibres is not so powerful.

The **ligamentum costo-xiphoidea** passes from the front of the upper part of the xiphoid cartilage, obliquely upwards and outwards to the front of the seventh, and sometimes to the front of the sixth costal cartilage.

Within the capsules of these joints **interarticular ligaments** (ligg. sterno-costalia interarticularia, Fig. 217) may be found. Their disposition is somewhat uncertain, for

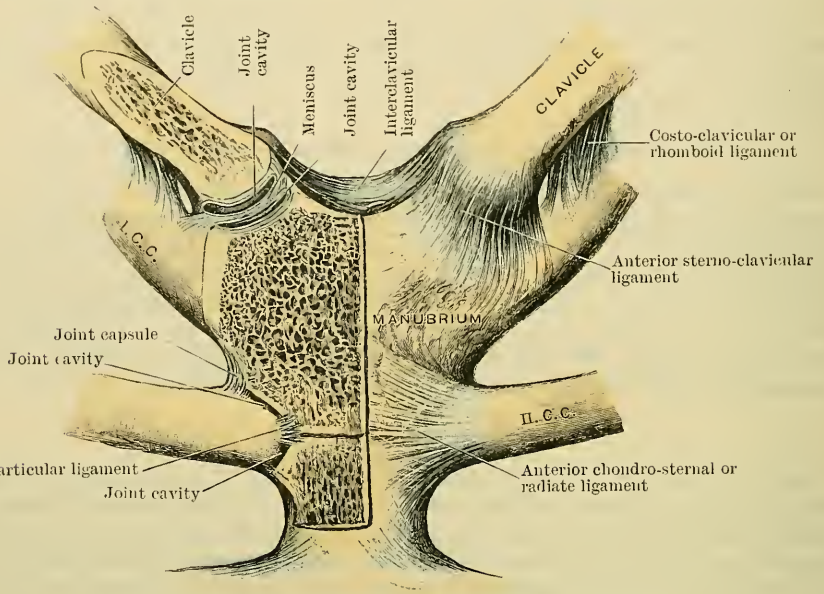


FIG. 217.—STERNO-CLAVICULAR AND COSTO-STERNAL JOINTS.

whereas, in the case of the second pair of cartilages, they invariably divide the joint cavity into two distinct compartments—an upper and a lower—such an arrangement is very uncertain in the other joints, and they occasionally, especially in the cases of the sixth and seventh cartilages, entirely obliterate the joint cavity. These ligaments extend horizontally between the ends of the costal cartilages and the side of the sternum.

Synovial membrane is found wherever a joint cavity is developed, and therefore there may be one or two synovial membranes, according to the presence or absence of a proper interarticular ligament. When the joint cavity is obliterated by the fibrous structure which represents the interarticular ligament, a synovial membrane is also absent.

STERNAL ARTICULATIONS.

Primarily the sternum consists of an elongated plate of hyaline cartilage, which becomes subdivided into segments by the process of ossification.

The four segments of which the **gladiolus** is originally composed unite with each other after the manner of typical synchondroses.

Similarly the ensiform cartilage and the gladiolus ultimately become united. It is not usual to find the manubrio-gladiolar joint obliterated by the ossification of the two bony segments. Even in advanced life it remains open, and the joint partakes of the nature of an amphiarthrosis (Fig. 217), although a joint cavity is not found under any circumstances in the plate of fibro-cartilage which intervenes between the manubrium and the gladiolus.

The **membrana sterni**, to which reference has already been made, assists in strengthening the union between the different segments of the sternum.

Movements of the Ribs and Sternum.—These movements may be considered either independently of, or as associated with, respiration.

In the former condition the ribs move in connexion with flexion and extension of the vertebral column, being more or less depressed and approximated in the former, and elevated or

pulled apart in the latter case. Considered in connexion with respiration, it is necessary to observe that, to all intents and purposes, the vertebral column and the sternum are rigid structures. Next we must remember that the heads of all the ribs occupy fixed positions, and similarly the anterior ends of seven pairs of cartilages are fixed to the lateral margins of the sternum. The ribs thus form arches, presenting a large amount of obliquity from behind forwards. Therefore, during inspiration, when the rib is elevated, the arch becomes more horizontal, and the transverse diameter of the chest is increased. At the same time, the anterior ends of the sternal ribs tend to thrust the sternum forwards and upwards; but the nature of the attachment of the first pair of ribs to the sternum, as well as the attachment of the diaphragm to the ensiform cartilage, prevents this movement from becoming excessive, and hence the sternum becomes a line of resistance to the forward thrust of the ribs. As a consequence, the ribs rotate upon themselves about an oblique axis which passes downwards, outwards, and backwards through the capitular joint and the neck of the rib anterior to the costo-transverse joint.

In this way increase, both of the antero-posterior and transverse diameters of the thorax, is provided for, although the amount of increase is not equally pronounced in all planes. Thus at the level of the first rib very little eversion is possible, because the axis of rotation is nearly transverse, and therefore any increase in the transverse or antero-posterior thoracic diameters at this level may be disregarded, although a certain amount of elevation of the manubrium sterni and anterior end of the first rib is evident.

Below the level of the sixth rib elevation and rotation of the rib during inspiration are usually said to be complicated by a certain amount of backward movement, due to the character of the costo-transverse joint, until, in the case of the last two ribs, which are destitute of costo-transverse joints, a movement backwards is almost entirely substituted for elevation. It is probable, however, that the movements of the asternal ribs exactly correspond to those of the sternal series, and that by the contraction of the costal digitations of the diaphragm the anterior ends of the asternal ribs are provided with fixed positions comparable to those supplied by the sternum to the ribs of the sternal series.

We may therefore say that during inspiration the ribs move upwards and outwards between their fixed ends, while as a whole the rib rotates, and its anterior end is thrust slightly forwards.

During expiration these movements are simply reversed.

THE ARTICULATIONS OF THE SUPERIOR EXTREMITY.

The bony arch formed by the clavicle and scapula articulates directly with the axial skeleton only at one point, viz. the sterno-clavicular joint.

ARTICULATIONS OF THE CLAVICLE.

The Sterno-clavicular Joint.

The sterno-clavicular joint (articulatio sterno-clavicularis) is an example of an arthrodial diarthrosis. The articular surfaces concerned in its formation present the following appearances:—

1. The sternal end of the clavicle is somewhat triangular in outline, having its most prominent angle directed downwards and backwards. The anterior and posterior sides of the triangle are slightly roughened for the attachment of ligaments, while the base or inferior side is smooth and rounded, owing to the prolongation of the articular surface to the inferior aspect of the bone. In the antero-posterior direction the articular surface tends to be concave, while vertically it is slightly convex.

2. An articular facet, situated on the superior lateral angle of the manubrium sterni, but in a plane slightly behind the supra-sternal notch, articulates with the clavicle. This facet is considerably smaller than the clavicular facet with which it articulates.

3. The superior surface of the first costal cartilage close to the sternum also participates to a small extent in the articulation.

It should be noted that the articular surfaces of the clavicle and sternum are covered mainly by **fibro-cartilage**.

A **capsular ligament** is well marked on all sides except inferiorly, where it is very thin.

The **anterior sterno-clavicular ligament** (Fig. 217) forms part of the capsule, and consists of short fibres which extend obliquely downwards and inwards from the anterior aspect of the sternal end of the clavicle to the adjoining anterior surface of the sternum and the anterior border of the first costal cartilage.

The **posterior sterno-clavicular ligament** also forms part of the capsule, and

consists of similarly disposed, but not so strong, oblique fibres situated on the posterior aspect of the articulation.

A **fibro-cartilaginous meniscus** (discus articularis, Fig. 217) divides the joint cavity into two compartments. It is nearly circular in shape, and adapts itself to the articular surfaces between which it lies. It is thickest at the circumference and thinnest at the centre, where it occasionally presents a perforation, thereby permitting the two synovial cavities to intercommunicate. By its circumference it is in contact with, and adherent to, the surrounding capsule, but its upper margin is attached to the apex of the articular surface of the clavicle, while by its lower margin it is fixed to the sternal end of the first costal cartilage.

Two **accessory ligaments** are associated with this joint, viz. the interclavicular and the rhomboid.

The **interclavicular ligament** (Fig. 217) is a structure of considerable strength, forming a broad band of fibrous tissue which is attached to the superior rounded angle or apex of the sternal end of the clavicle as well as to the adjacent margins of the articular surface. Its fibres pass across the interclavicular notch to become attached to corresponding parts of the opposite clavicle, but in their course they dip down into the suprasternal notch, in which many of them are fixed to the sternum. In this way their presence neither bridges nor obliterates the notch between the two clavicles, and the ligament really becomes a superior sterno-clavicular ligament for each joint.

The **rhomboid ligament** (lig. costo-claviculare, Fig. 217) consists of short, strong fibres which are attached inferiorly to the upper surface of the first costal cartilage. They pass obliquely upwards and outwards to a rough impression situated on the lower aspect of the sternal end of the clavicle, and are distinct from the capsular ligament. Occasionally a bursa is found in the interior of this ligament.

As a rule there are two **synovial membranes** lining the two joint cavities (Fig. 217), separated from each other by the interarticular meniscus. Sometimes, however, the two membranes establish continuity through a perforation in the meniscus.

The Acromio-clavicular or Scapulo-clavicular Joint.

The acromio-clavicular joint (articulatio acromio-clavicularis) is another instance of an arthrodial diarthrosis. It is situated between the acromial end of the clavicle and the inner aspect of the acromion process of the scapula. Each articular surface is an oval, flattened facet, covered by **fibro-cartilage.**

The **ligaments** which surround this small joint form a complete **capsule** (capsula articularis), of which the upper and lower parts are specially strong, and are therefore named the **superior** and **inferior acromio-clavicular ligaments** (Fig. 219). These consist of short fibres passing between the adjacent rough margins of the two bones in the positions indicated by their names.

A **meniscus** (discus articularis), which is nearly always incomplete, and may occasionally be wanting, is usually found within the joint cavity, where it lies obliquely, with its upper margin farther from the mesial plane than its lower margin, and having its borders attached to the surrounding capsule. Frequently the meniscus is wedge-shaped, with its base directed upwards and its apex free.

A **synovial membrane** is found forming either a single or a double sac, according to the condition of the meniscus. Complete division of the joint cavity, however, is rare.

Ligamentum Coraco-claviculare.—Accessory to this articulation there is the strong **coraco-clavicular ligament** which binds the acromial end of the clavicle to the coracoid process of the scapula. It is readily divisible into two parts, viz. the conoid and trapezoid ligaments.

The **conoid ligament** (Fig. 219) is situated internal to and slightly behind the trapezoid. It is narrow and pointed at its inferior end, by which it is attached to the upper aspect of the coracoid process, in close proximity to the suprascapular notch. Its upper end widens out in the manner expressed by its name, and is attached to the conoid tubercle of the clavicle.

The **trapezoid ligament** (Fig. 219) is attached inferiorly to the upper surface of the posterior half of the coracoid process, external and anterior to the attachment of

the conoid ligament. Superiorly it is attached to the trapezoid ridge on the under surface of the acromial end of the clavicle. Its outer and inner borders are free. Its anterior surface is principally directed upwards, and its posterior surface, to a similar extent, looks downwards.

A **synovial bursa** usually occupies the re-entrant angle between these two ligaments.

Movements at the Clavicular Joints.—The movements of the inner end of the clavicle at the **sterno-clavicular joint** are limited in their range, owing to the tension of the ligaments. When the shoulder is raised or depressed the outer end of the clavicle moves upwards and downwards, whilst its sternal end glides upon the surface of the interarticular meniscus within the joint; when, on the other hand, the shoulder is carried forwards or backwards, the inner end of the clavicle along with the interarticular meniscus moves upon the sternal facet. In addition to these movements of elevation, depression, forward movement and backward movement of the clavicle, there is also allowed at the sterno-clavicular joint a certain amount of circumduction of the clavicle.

The part which is played by certain of the ligaments in restraining movement requires careful consideration. The **rhomboid ligament** checks excessive elevation of the shoulder, and restrains within certain limits both backward and forward movement of the clavicle. When the clavicle is depressed, as in cases where a heavy weight, such as a bucket of water, is carried in the hand, it receives support by resting upon the first rib, and the tendency for the inner end of the bone to start up out of its sternal socket is obviated by the tension of the **interarticular meniscus**, the **interclavicular ligament**, and the **anterior** and **posterior sterno-clavicular ligaments.**

The **interarticular meniscus** not only acts as a cushion which lessens the shock of blows received upon the shoulder, but it also acts as a most important bond of union, and prevents the inner end of the clavicle from being driven upwards upon the top of the sternum when force is applied to its outer end.

The movements at the **acromio-clavicular joint** are of such a kind as to allow the inferior angle, and to some extent the base of the scapula, to remain more or less closely applied to the chest-wall during the various movements of the shoulder. The strong connexion between the coracoid process and the acromial end of the clavicle, by means of the conoid and trapezoid ligaments, renders it necessary that the scapula should follow the clavicle in its various excursions. The presence of the acromio-clavicular joint, however, enables the scapula to change its position somewhat with reference to the clavicle as the shoulder is moved. Thus, when the shoulder is raised and depressed, a marked difference takes place in the angle between the two bones; again, when the shoulder is thrown forwards or backwards, these movements can be performed without altering in a material degree the direction of the glenoid cavity of the scapula, or in other words, the socket of the shoulder-joint.

The **conoid** and **trapezoid ligaments** set a limit upon the movements of the scapula at the acromio-clavicular joint. They both, but more particularly the trapezoid ligament, prevent the acromion process of the scapula from being carried inward below the outer end of the clavicle when blows fall upon the outer aspect of the shoulder.

Ligaments of the Scapula.

These ligaments are not directly connected with any articulation. The **coraco-acromial ligament** (lig. coraco-acromiale, Fig. 219) completes the arch between the coracoid and acromion processes of the scapula, and thus provides a secondary socket for the greater protection and security of the shoulder-joint. It is a flat triangular structure stretched tightly between its lines of attachment. By its base it is fixed to a varying amount of the postero-external border of the coracoid process, and by its narrower apical end to the tip of the acromion process, immediately external to the acromio-clavicular joint. Its surfaces look upwards and downwards, and its free borders outwards and inwards. It is thinnest in the centre, where it is sometimes perforated by a prolongation of the tendon of the pectoralis minor muscle.

The **suprascapular ligament** (lig. transversum scapulæ superius) is a distinct but short flat band which bridges the notch of the same name. It may be continuous with the conoid ligament, and it is frequently ossified. As a rule the foramen completed by this ligament transmits the suprascapular nerve, while the corresponding vessels travel above the ligament to reach the supraspinous fossa.

A small duplicate of this ligament may often be found bridging the foramen on its ventral aspect, subjacent to which small branches of the suprascapular artery return from the supraspinous to the subscapular fossa.

The **spino-glenoid ligament** (lig. transversum scapulæ inferius) consists of another set of bridging fibres which are situated on the posterior aspect of the

neck of the scapula. By one end they are attached to the external border of the scapular spine, and by the other to the adjacent part of the posterior aspect of the head of the scapula. The suprascapular nerve and vessels pass subjacent to this ligament.

THE SHOULDER-JOINT.

The shoulder-joint (articulatio humeri) is one of the largest as well as the most important of the joints of the upper limb. It is an example of the enarthrodial, *i.e.* ball-and-socket variety of a diarthrosis, and, at the cost of a certain amount of security, it has obtained an extended range of movement.

The bones which enter into its formation are the glenoid fossa of the scapula and the head of the humerus.

The glenoid fossa is a shallow pyriform articular surface, having its narrow end directed upwards and slightly forwards. The upper half of the anterior margin of the fossa is characterised by a shallow notch which accommodates the narrow part of the subscapularis muscle as it runs outwards to its insertion. At the apex of the fossa there is a flat area for the attachment of the long tendon of the biceps flexor cubiti muscle. The head of the humerus is hemispherical and articular, while, external to its articular margin, there is a slight constriction (the anatomical or true neck of the humerus), which is most strongly marked in relation to the greater and lesser tuberosities of the humerus.

Under ordinary conditions the two articular surfaces are maintained in apposition by muscular action, aided by atmospheric pressure, and thus, when the muscles are removed, the bones fall asunder to the full extent of the restraining ligaments. Only a small part of the humeral head is in contact with the glenoid fossa at any particular moment, because the former is much larger than the latter, but, by reason of the shallow character of this fossa, all parts of the two articular surfaces may successively be brought into contact with each other.

In the position of rest, as the limb hangs parallel to the vertical axis of the trunk, the inferior aspect of the neck of the humerus is brought into close relation with the lower part of the glenoid fossa.

The **glenoid ligament** (labrum glenoidale, Fig. 219) deepens the glenoid fossa, and thus extends the articular surface. It is situated within the joint capsule, and to some slight extent increases the security of the articulation. It consists of a strong ring of dense fibrous tissue attached to the free margin of the glenoid fossa. Many of its fibres are short, and pass obliquely from the inner to the outer aspect of the ridge, so that its attached base is broader than its free edge, and therefore in cross section it appears somewhat triangular. The long tendon of the biceps, which arises from the apex of the glenoid fossa, becomes to a considerable extent incorporated with this ligament.

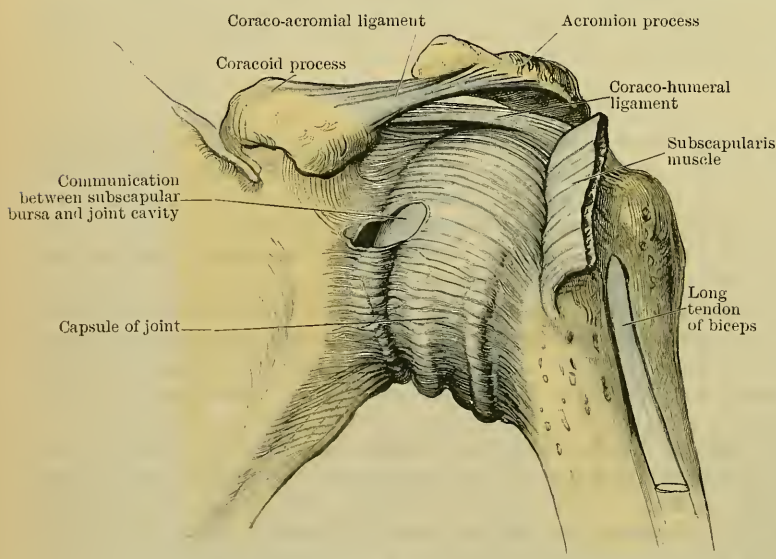


FIG. 218.—CAPSULE OF THE SHOULDER-JOINT AND CORACO-ACROMIAL LIGAMENT.

The **capsular ligament** (capsula articularis, Fig. 218) presents the general shape which is characteristic of the corresponding ligament in other ball-and-socket joints,

viz. a hollow cylinder. By its upper end the capsule is attached to the circumference of the glenoid fossa, external to the glenoid ligament, and also, to a considerable extent, to the glenoid ligament itself.

By its lower end it is attached to the neck of the humerus, and therefore beyond the articular area of the head. The capsule is strongest on its superior aspect, while inferiorly, where the neck of the bone is least defined, it extends downwards for a short distance upon the humeral shaft. Its fibres for the most part run longitudinally, but a certain number of them pursue a circular direction.

A prolongation of the capsule, the **transverse humeral ligament** presenting both longitudinal and transverse fibres, bridges that part of the bicipital groove which is situated between the tuberosities of the humerus. At this point an interruption in the capsule, beneath the transverse humeral ligament, permits the long tendon of the biceps to escape from its interior. In addition to the opening just referred to, there is another very constant deficiency in the upper and anterior part of the capsule, where the narrowing tendon of the subscapularis muscle is brought into contact with a bursa formed by a protrusion of the synovial membrane. This defect in the capsule has its long axis in the direction of the longitudinal fibres. Occasionally there is a similar but smaller opening under cover of the tendon of the infraspinatus muscle. Through the two latter openings the joint cavity communicates with bursæ situated between the capsule and the muscles referred to.

The tendons of the subscapularis, supraspinatus, and infraspinatus muscles fuse with, and so strengthen, the capsule as they approach their respective insertions.

On the superior aspect of the articulation the capsule is augmented by an accessory structure, the **ligamentum coraco-humerale** (Fig. 218). By its inner end, which is situated immediately above the glenoid fossa, but subjacent to the coraco-acromial ligament, it is attached to the external border of the root of the coracoid process, while its outer end is attached to the humeral neck close to the great tuberosity. This ligament forms a flattened band, having its hinder and lower border fused with the capsule, but its anterior and upper margin presents a free edge, slightly raised above the level of the capsule. This structure is believed to represent that portion of the pectoralis minor to which reference has already been made in connexion with the coraco-acromial ligament (p. 275).

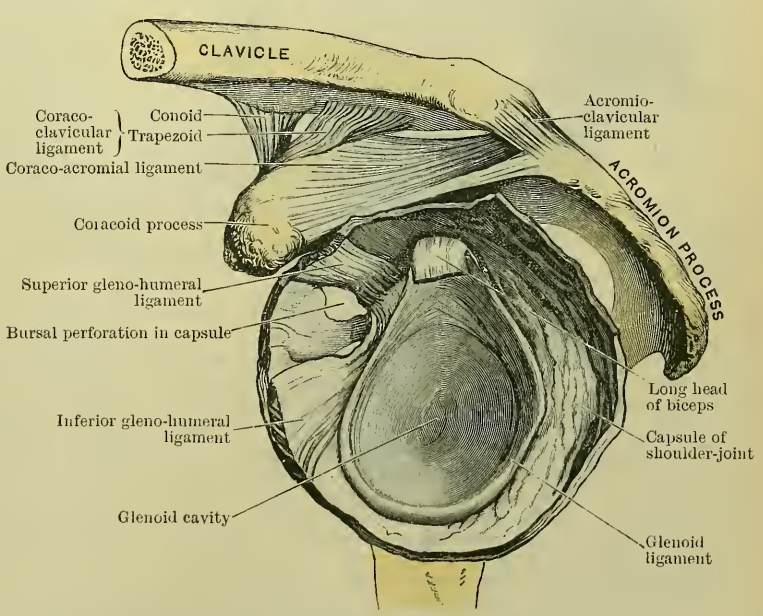


FIG. 219.—CAPSULAR LIGAMENT OF SHOULDER-JOINT CUT ACROSS AND HUMERUS REMOVED.

The **coraco-glenoid ligament** is another accessory structure which is not always present. It springs from the coracoid process along with the former ligament, and extends to the upper and hinder margin of the head of the scapula.

Gleno-humeral Ligaments (Fig. 219).—If the capsule be opened from behind, and the head of the humerus be removed, it will be seen that the longitudinal fibres of the anterior part of the capsule are specially developed in the form of thick flattened bands which extend from the anterior border of the glenoid fossa to the anterior aspect of the neck of the humerus. These gleno-humeral

ligaments are three in number, and occupy the following positions : the **superior** is placed *above* the aperture in the front of the capsule ; the **middle** and **inferior** on the antero-inferior aspect of the capsule, and *below* the aperture mentioned.

The superior gleno-humeral ligament, which some believe to represent the ligamentum teres of the hip-joint, springs, along with the middle gleno-humeral band, from the upper part of the anterior glenoid margin. The inferior band is the strongest of the three, and springs from the lower part of the anterior glenoid margin.

Intra-capsular Structures.—1. The glenoid ligament, already described. 2. The long tendon of the biceps passes outwards from its attachment to the apex of the glenoid fossa and the adjoining part of the glenoid ligament, above the head and neck of the humerus, to escape from the interior of the capsule by the opening between the tuberosities of the humerus, subjacent to the transverse humeral ligament.

Synovial membrane (Fig. 220) lines the capsule of the joint, and extends from the margin of the glenoid fossa to the humeral attachments of the capsule, where it is reflected towards the margin of the articular cartilage. It is therefore important to note that the inferior aspect of the humeral neck has the most extensive clothing of synovial membrane. Further, the synovial membrane envelops the intra-capsular part of the tendon of the biceps, and although this tubular sheath is prolonged upon the tendon into the upper part of the bicipital groove, yet the closed character of the synovial cavity is maintained. Thus, while the tendon is within the capsule, it is not within the synovial cavity. The synovial membrane is continuous with those bursæ which communicate with the joint cavity through openings in the ligamentous capsule.

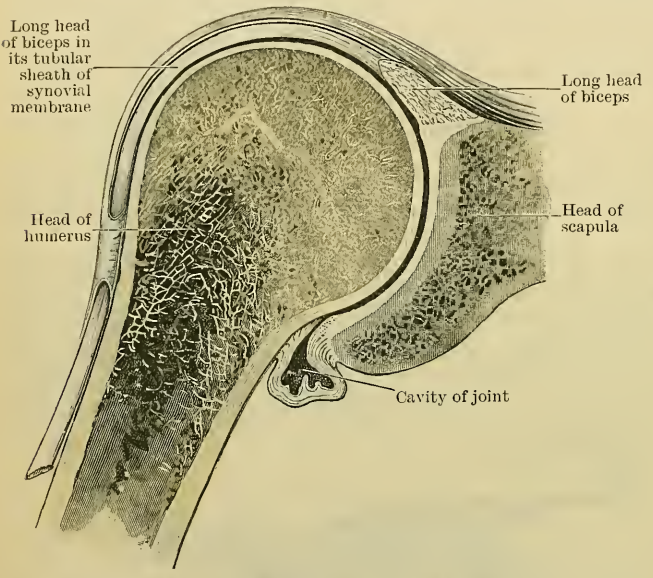


FIG. 220.—VERTICAL SECTION THROUGH THE SHOULDER-JOINT.

Bursæ (*a*) *Communicating with the Joint Cavity.*—Practically there is only one bursa which is constant in its position, viz. the **subscapular**, between the capsule and the tendon of the subscapularis muscle. It varies considerably in its dimensions, but its lining membrane is always continuous with that which lines the capsule (Figs. 217 and 218), and therefore it may be regarded merely as a prolongation of the articular synovial membrane. Occasionally a similar but smaller bursa occurs between the capsule and the tendon of the infraspinatus muscle.

(*b*) *Not communicating with the Joint Cavity.*—The **sub-deltoid** or **sub-acromial bursa** is situated between the muscles on the superior aspect of the shoulder-joint on the one hand and the deltoid muscle on the other. It is an extensive bursa, and is prolonged subjacent to the acromion process and the coraco-acromial ligament. It does not communicate with the shoulder-joint, but it greatly facilitates the movements of the upper end of the humerus against the under surface of the coraco-acromial arch.

Movements at the Shoulder-Joint.—A ball-and-socket joint permits of a great variety of movements, practically in all directions ; but if these movements be analysed, it will be seen that they resolve themselves into movements about **three** primary axes at right angles to each other, or about axes which are the possible combinations of the primary ones.

Thus, about a transverse axis, the limb may move forwards (**flexion**) or backwards (**extension**). About an antero-posterior axis it may move outwards, *i.e.* away from the mesial plane of the trunk (**abduction**), or inwards, *i.e.* towards, and to some extent up to, the mesial plane (**adduction**).

About a vertical axis, the humerus may **rotate** upon its axis in an inward or outward direction to the extent of a quarter of a circle.

Since these axes all pass through the shoulder-joint, and since each may present varying degrees of obliquity, it follows that very elaborate combinations are possible until the movement of **circumduction** is evolved. In this movement the head of the humerus acts as the apex of a **cone of movement** with the distal end of the humerus, describing the base of the cone.

The range of the shoulder-joint movements is still further increased from the mobility of the scapula as a whole, and from its association with the movements of the clavicle already described.

THE ELBOW-JOINT.

This articulation (articulatio cubiti) provides an instance of a diarthrosis capable of performing the movements of flexion and extension about a single axis placed transversely, *i.e.* a typical ginglymus diarthrosis or hinge-joint.

The bones which enter into its formation are the humerus, ulna, and radius. The trochlea of the humerus articulates with the greater sigmoid cavity of the ulna (articulatio humero-ulnaris); the capitellum of the humerus articulates with the shallow depression or cup on the superior aspect of the head of the radius (articulatio humero-radialis). The articular cartilage clothing the trochlea of the humerus terminates in a sinuous or concave margin both anteriorly and posteriorly, so that it does not line either the coronoid or the olecranon fossa. Internally, it merely rounds off the inner margin of the trochlea, but externally it is continuous with the encrusting cartilage covering the capitellum, to the margin of which the cartilage extends in all directions, and thus it presents a convex edge in relation to the supra-capitellar or radial fossa. The cartilage which lines the greater sigmoid cavity of the ulna presents a transverse interruption, considerably wider on its inner as compared with its outer aspect. Thereby the coronoid and olecranon segments of the fossa are separated from each other. The cartilage which clothes the coronoid segment is continuous with that which clothes the lesser sigmoid cavity. The shallow cup-shaped depression on the head of the radius is covered by cartilage which rounds off the margin, and is prolonged without interruption upon the vertical aspect of the head, descending to its lowest level on that part opposed to the lesser sigmoid cavity.

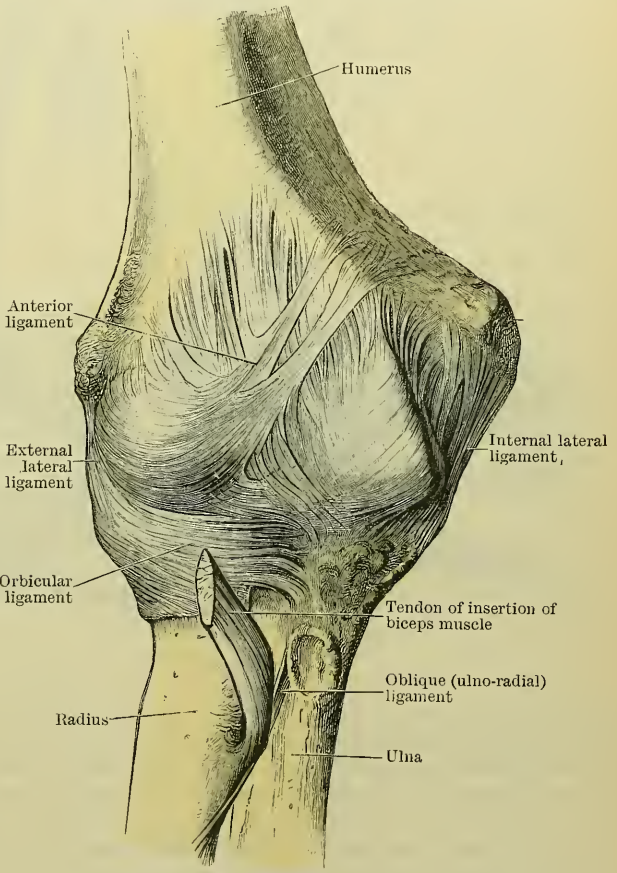


Fig. 221.—Anterior View of Elbow-Joint.

Ligaments.—Taken as a whole, the ligaments form a complete **capsule** (capsula articularis), which is not defective at any point, although it is not of equal thickness throughout, and certain bands of fibres stand out distinctly because of their greater strength.

The **anterior ligament** (Fig. 221) consists of a layer whose fibres run in several

directions—obliquely, transversely, and vertically—and of these the vertical fibres are of most importance. It is attached above to the upper margins of the coronoid and supracapitellar fossæ; below, to the margins of the coronoid process and to the orbicular ligament of the superior radio-ulnar joint, but some loosely arranged fibres reach as far as the neck of the radius. The lateral portions of this ligament, which are situated in front of the capitellum and the inner margin of the trochlea respectively, are much thinner and weaker than the central part. Fibres of origin of the brachialis anticus muscle are attached to the front of this ligament.

The **posterior ligament** is an extremely thin, almost redundant layer. Superiorly it is attached, in relation to the margin of the olecranon fossa, at a varying distance from the trochlear articular surface, and inferiorly to the summit and sides of the lip of the olecranon process. Externally some of its fibres pass from the posterior aspect of the capitellum to the posterior border of the lesser sigmoid cavity of the ulna. This ligament derives material support from, and participates in the movements of, the triceps extensor cubiti muscle, since they are closely adherent to each other in the region of the olecranon process.

The **internal lateral ligament** (lig. collaterale ulnare, Figs. 221 and 222) is a fan-

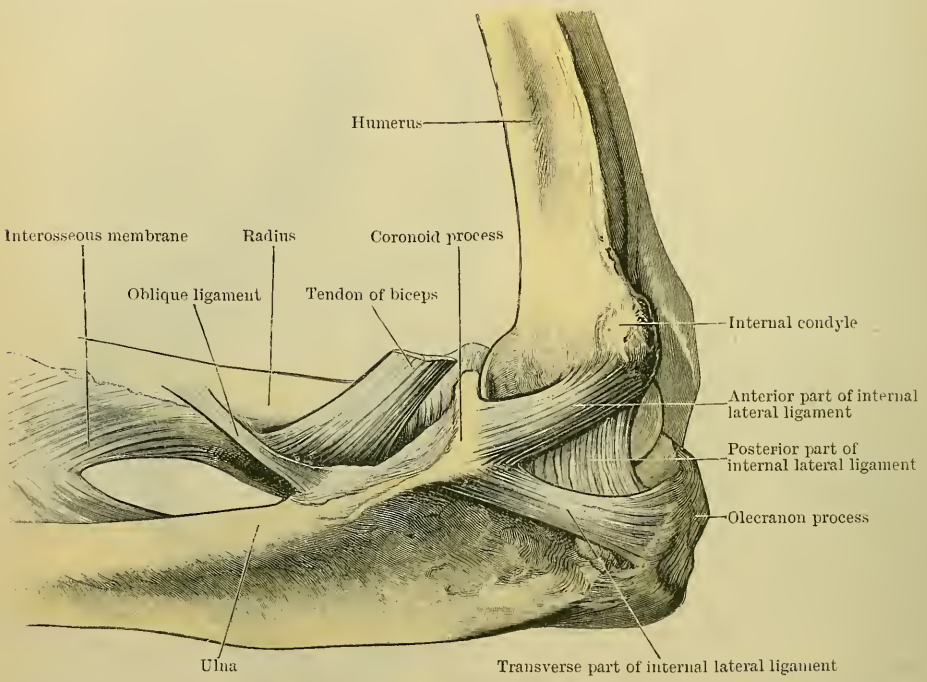


FIG. 222.—ELBOW-JOINT (inner aspect).

shaped structure of unequal thickness, but its margins, which are its strongest bands, are continuous with the adjoining parts of the anterior and posterior ligaments. By its upper end it is attached to the anterior, inferior, and posterior aspects of the internal condyle of the humerus. By its broad lower end it is attached to the inner margin of the greater sigmoid cavity, so that the *anterior band* is associated principally with the inner margin of the coronoid process, and the *posterior band* with the inner margin of the olecranon process, while the intermediate weaker portion sends its fibres downwards to join a *transverse band*, sometimes very strong, which bridges the notch between the adjoining inner margins of the coronoid and olecranon processes.

The **external lateral ligament** (lig. collaterale radiale, Fig. 221) is a strong flattened band attached superiorly to the lower and posterior aspects of the external condyle of the humerus. It completes the continuity of the capsule on the outer side, and blends inferiorly with the orbicular ligament, on the surface of which its fibres may be traced both to the anterior and posterior ends of the lesser sigmoid

notch. Both of the lateral ligaments are intimately associated with the muscles which take origin from the inner and outer condyles of the humerus.

Synovial Pads of Fat (Fig. 223).—Internal to the capsule, there are several pads of fat situated between it and the synovial membrane. Small pads are so placed as to lie immediately in front of the coronoid and supra-capitellar fossæ, but a larger one projects towards the olecranon fossa.

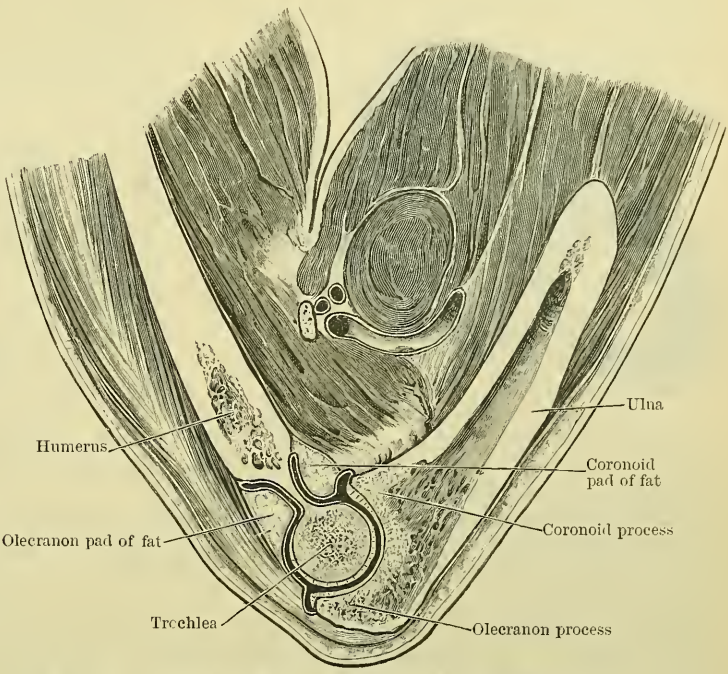


FIG. 223.—VERTICAL SECTION THROUGH THE TROCHLEAR PART OF THE ELBOW-JOINT.

Synovial membrane (Fig. 223) lines the entire capsule and clothes the pads of fat above referred to, as well as those portions of bone enclosed within the capsule which are not covered by articular cartilage. By its disposition the elbow and the superior radio-ulnar joints possess a common joint cavity. It should be specially noted that the upper part of the neck of the radius is surrounded by this synovial membrane.

Movements at the Elbow-Joint.—The movements of the radius and ulna upon the humerus have already been referred to as those characterising a uniaxial joint constructed on the plan of a hinge. In this case the axis of the joint is obliquely transverse, so that in the extended position the humerus and ulna form an obtuse angle open towards the radius, whereas in the flexed position the hand is carried inwards in the direction of the mouth. Extreme flexion is checked by the soft parts in front of the arm and of the fore-arm coming into contact, and extreme extension by the restraining effect of the ligaments and muscles. In each case the movement is checked before either coronoid or olecranon processes come into contact with the humerus. The anterior and posterior bands of the internal lateral ligament are important factors in these results. Lateral movement of the ulna is not a characteristic movement, although it may occur to a slight extent, owing to a want of complete adaptation between the trochlear surface of the humerus and the sigmoid cavity of the ulna. This incongruence is noteworthy since the inner lip of the trochlea is prominent in front, and the outer lip is prominent behind. Consequently, this latter part is associated with a surface on the outer side of the olecranon which is only utilised in complete extension.

The capitellum and the opposing surface upon the head of the radius are always in varying degrees of contact. The head of the radius participates in the movements of flexion and extension, and is most closely and completely in contact with the humerus during the position of semi-flexion and semi-pronation. In complete extension a very considerable part of the capitellum is uncovered by the radius.

THE RADIO-ULNAR JOINTS.

These articulations, which are two in number, are situated at the proximal and distal ends of the radius and ulna. They provide an adaptation whereby the radius rotates around a longitudinal axis in the movements of pronation and supination, and hence this form of uniaxial diarthrosis is termed lateral ginglymus.

Superior Radio-ulnar Joint (articulatio radio-ulnaris proximalis).—In this joint the articular surfaces which enter into its formation are the lesser sigmoid cavity of the ulna and the lateral aspect of the head of the radius. In each case the articular cartilage is continuous with an articular surface entering into the formation of the elbow-joint, consequently the joint cavity is continuous with that

of the elbow-joint, and therefore, in a sense, it lies within the cover of the capsule of the elbow-joint; but its special feature is the—

Orbicular ligament (lig. annulare radii, Figs. 221 and 224), which has formerly been mentioned as the inferior line of attachment of the external lateral ligament and the ligaments on the front and back of the elbow-joint.

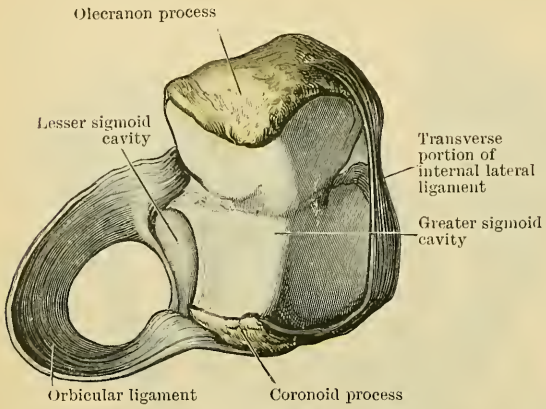


FIG. 224.—ORBICULAR LIGAMENT OF THE RADIUS.

It is a strong, well-defined structure, attached by its extremities to the anterior and posterior margins of the lesser sigmoid cavity, and thus it forms nearly four-fifths of an osseo-tendinous circle or ring. This circle is somewhat wider at the upper than at the lower margin of the orbicular ligament, which, by encircling the upper part of the neck of the radius, tends to prevent displacement of the head of that bone in a downward direction. The lower margin of this ligament is not directly attached to the radius.

The **synovial membrane** is continuous with that which lines the elbow-joint. It closes the joint cavity at the inferior unattached margin of the orbicular ligament, where it is somewhat loosely arranged in its reflexion from the ligament to the neck of the radius.

Inferior Radio-ulnar Joint (articulatio radio-ulnaris distalis).—This joint is situated between the sigmoid cavity on the inner side of the lower end of the radius and the lateral aspect of the head of the ulna. In addition, it includes the inferior surface of the head of the ulna, which articulates with the superior surface of a triangular plate of fibro-cartilage, by means of which the joint is excluded from the radio-carpal articulation

The **triangular interarticular fibro-cartilage** (discus articularis, Figs. 225 and 227), besides presenting articular surfaces to two separate joints, is an important ligament concerned in binding together the lower ends of the radius and ulna. It is attached by its apex to the depression at the outer side of the root of the styloid process of the ulna, and by its base to the sharp line of demarcation between the sigmoid cavity and the carpal articular surface of the radius.

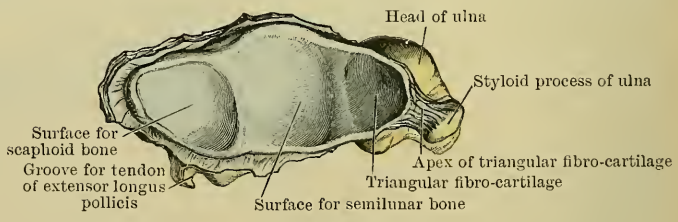


FIG. 225.—CARPAL ARTICULAR SURFACE OF THE RADIUS, AND TRIANGULAR FIBRO-CARTILAGE OF THE WRIST.

The **ligamentous capsule** is very imperfect, and consists of scattered fibres, termed the **anterior** and **posterior radio-ulnar** ligaments (Fig. 226). These ligaments pass transversely between adjoining non-articular surfaces on the radius and ulna, and are of sufficient length to permit of the movements of the radius in pronation and supination.

The **synovial membrane** completes the closure of the joint cavity. It forms a loose bulging projection (recessus sacciformis), passing upwards between the lower ends of the shafts of the radius and ulna, and it also clothes the upper surface of the triangular fibro-cartilage (Fig. 227). The cavity of this joint is quite distinct from that of the radio-carpal articulation, except when the triangular fibro-cartilage presents a perforation.

Between the foregoing articulations there are two **accessory ligaments**, viz. the interosseous membrane and the oblique ligament, which connect together the shafts of the radius and ulna.

The **interosseous membrane** (Fig. 222) of the fore-arm (membrana interossea interbrachii) is a strong fibrous membrane which stretches across the interval between the radius and ulna, and is firmly attached to the interosseous border of each. Below it extends downwards to the lower limit of the space between the bones, whilst above it does not reach higher than a point about one inch below the tuberosity of the radius. A gap, called the *hiatus interosseus*, is thus left above its upper margin, and through this the posterior interosseous vessels pass backwards between the bones to reach the dorsal aspect of the fore-arm. This gap is bounded above by the oblique ligament. The fibres which compose the interosseous membrane run for the most part downwards and inwards from the radius to the ulna, although on its dorsal aspect several bands may be observed stretching in an opposite direction. The interosseous membrane augments the surface available for the origin of the muscles of the fore-arm; it braces the radius and ulna together; and when shocks are communicated from the hand to the radius, owing to the direction of its fibres, the interosseous membrane transmits these, to some slight extent, to the ulna.

The **oblique ligament** (Fig. 222) is a slender tendinous band of very varying strength which springs from the outer part of the coronoid process of the ulna, and stretches obliquely downwards and outwards to the radius where it is attached immediately below the bicipital tuberosity.

Movements of the Radius on the Ulna.—The axis about which the radius moves is a longitudinal one, having one end passing through the centre of the head of the radius and the other through the styloid process of the ulna and the line of the ring-finger. In this axis the head of the radius is so secured that it can only rotate upon the lesser sigmoid cavity of the ulna within the orbicular ligament, and consequently the radial head remains upon the same plane as the ulna; but the lower end of the radius being merely restrained by the triangular fibro-cartilage, is able to describe nearly a half-circle, of which the apex of this ligament is the centre. In this movement the radius carries the hand from a position in which the palm is directed forwards, and in which the radius and ulna lie parallel to each other (**supination**), to one in which the palm is directed backwards, and the radius lies diagonally across the front of the ulna (**pronation**).

The ulna is unable to rotate upon a long axis, but while the radius is travelling through the arc of a circle from without inwards in front of the ulna, it will usually be seen that the ulna appears to move through the arc of a smaller circle in the reverse direction, viz. from within outwards. If the humerus be prevented from moving at the shoulder-joint, a very large proportion, if not the entire amount, of this apparent movement of the ulna will disappear. At the same time some observers maintain that it really occurs at the elbow-joint, associated with lateral movement during slight degrees of flexion and extension at that joint.

THE RADIO-CARPAL JOINT.

This joint (articulatio radiocarpea) is a bi-axial diarthrosis, frequently called a condyloid joint.

The articular elements which enter into its formation are: on its *proximal side*, the inferior surface of the lower end of the radius, together with the inferior surface of the triangular fibro-cartilage; on its *distal side*, the superior articular surfaces of the scaphoid, semilunar, and cuneiform bones. The articular surface of the radius is concave both in its antero-posterior and transverse diameters, in order to adapt itself to the opposing surfaces of the scaphoid and semilunar, which are convex in the two axes named. In the ordinary straight position of the hand the triangular fibro-cartilage is in contact with the semilunar bone, and the upper articular surface of the cuneiform bone is in contact with the capsule of the joint. When, however, the hand is bent towards the ulna, the cuneiform bone is carried outwards as well as the semilunar and scaphoid, and the triangular fibro-cartilage comes into contact with the cuneiform. The articular surface of the radius is subdivided by an antero-posterior, slightly elevated ridge, into an outer triangular facet which usually articulates with the scaphoid, and an inner quadrilateral facet for articulation with a portion of the semilunar bone.

In the intervals between the scaphoid, semilunar, and cuneiform bones, the continuity of the articular surfaces is usually maintained by the presence of interosseous ligaments which are situated upon the same level as the articular cartilage.

Ligaments.—A capsular ligament completely surrounds the joint. It is somewhat loosely arranged, and permits of subdivision into the following portions:—

The **external lateral ligament** (Fig. 226) is a well-defined band which is attached

by one end to the tip of the styloid process of the radius, and by the other to a rough area at the base of the tubercle of the scaphoid bone, *i.e.* external to its radial articular surface.

The **internal lateral ligament** (Fig. 226) is also a distinct rounded structure, having one end attached to the tip of the styloid process of the ulna, and the other to the rough non-articular border of the cuneiform bone, some of its fibres being prolonged to the pisiform bone.

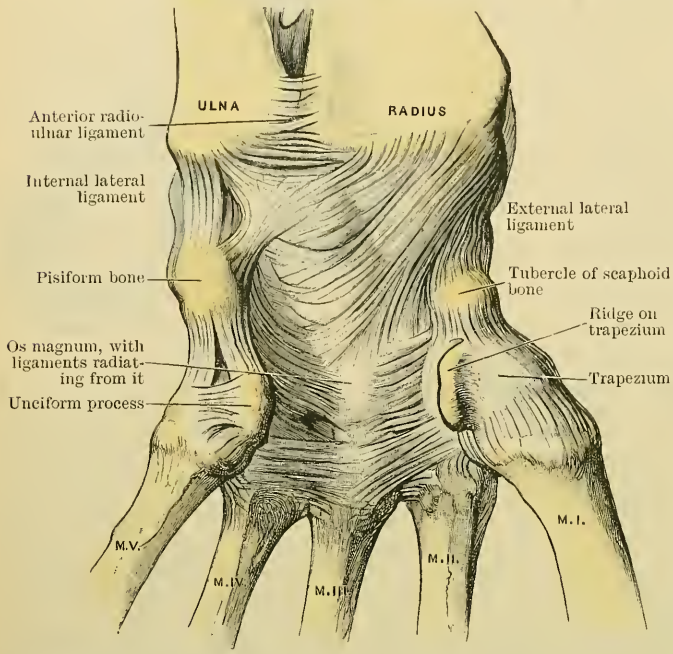


Fig. 226.—Ligaments on Anterior Aspect of Radio-carpal, Carpal, and Carpo-metacarpal Joints.

The **anterior ligament** (Fig. 226) is attached superiorly to the anterior margin of the lower end of the radius, as well as slightly to the base of the styloid process of the ulna. Some transverse fibres may be seen, but the greater number pass obliquely downwards and inwards to the palmar non-articular surfaces of the scaphoid, semilunar, and cuneiform bones, while some of them may even be continued as far as the os magnum. Those fibres from the ulna run obliquely outwards. On its deeper aspect this ligament is closely adherent to the anterior border of the triangular fibro-cartilage of the inferior radio-ulnar articulation.

The **posterior ligament** extends from the posterior margin of the lower end of the radius, obliquely downwards and inwards, to the dorsal non-articular areas on the proximal row of the carpal bones. The slip to the latter assists in forming the fibrous sheath through which the tendon of the extensor carpi ulnaris muscle travels to its insertion. The principal bundle of fibres is connected with the cuneiform bone.

The **synovial membrane** (Fig. 227) is simple, and is confined to the articulation, except in those cases in which the triangular fibro-cartilage is perforated, or in which one of the interosseous ligaments between the carpal bones of the first row is absent.

Movements at the Radio-carpal Joint.—The radio-carpal joint affords an excellent example of a biaxial articulation, in which a long transverse axis of movement is situated more or less at right angles to a short axis placed in the antero-posterior direction. The nature of the movements which are possible about these two axes is essentially the same in both cases, viz. **flexion** and **extension**. The movements about the longer transverse axis are anterior or palmar flexion, extension, and its continuation into dorsi-flexion. About the shorter antero-posterior axis we get movements which result from combined action by certain flexor and extensor muscles, whereby the radial or ulnar borders of the hand may be approximated towards the corresponding borders of the fore-arm. Lateral movement may also be possible to a slight extent. The range of movement in connexion with either of the principal axes is largely a matter of individual peculiarity, for, with the exception of the lateral ligaments, there is no serious obstacle to the cultivation of greater mobility at the radio-carpal joint.

CARPAL JOINTS.

The articulations subsisting between the individual carpal bones (articulationes intercarpeæ) are all diarthroses, and although the total amount of movement throughout the series is considerable, yet the extent of movement which is possible

between the two rows or between any two carpal bones is extremely limited. For this reason, as well as because of the nature of the movement, these articulations are called gliding joints (arthrodia).

It is advisable to consider, *first*, the articulations between individual bones of the proximal row; *second*, the articulations between the separate bones of the distal row; *third*, the articulation of the proximal and distal rows with each other; *fourth*, the pisiform articulation.

The **proximal row of carpal articulations** (Fig. 226) comprises the joints between the scaphoid, semilunar, and cuneiform bones. On their adjacent lateral aspects these bones are partly articular and partly non-articular.

Three sets of simple but strong, although short ligamentous bands bind these three carpal bones together, and form an investment for three sides of their intercarpal joints. These are—(1) the **anterior** or **palmar ligaments**, two in number, which consist of transverse fibres passing between the adjacent rough palmar surfaces of the bones; (2) the **posterior** or **dorsal ligaments**, also two in number, and composed of similar short transverse fibres passing between the adjacent dorsal surfaces; (3) the **interosseous ligaments** (Fig. 227), again two in number, and transverse in direction, situated on a level with the superior articular surfaces, and extending from the palmar to the dorsal aspect of the bones, while attached to non-articular areas of the opposing surfaces. The radio-carpal joint is entirely shut off from the intercarpal joints, and also from the joint between the two rows of carpal bones, except in rare cases, when an interosseous ligament is wanting.

The **distal row of carpal articulations** (Fig. 226) includes the joints between the trapezium, trapezoid, os magnum, and unciform bones. Articular facets occur on the opposing lateral faces of the individual bones.

Associated with this row there are again simple bands of considerable strength, and presenting an arrangement similar to that seen in the proximal row. As in the former case, they invest the intercarpal articulations, except on the superior aspect, where they communicate with the transverse carpal joint, and on the inferior aspect, where they communicate with the carpo-metacarpal joint cavity.

The **anterior** or **palmar ligaments** are three in number. They extend in a transverse direction between contiguous portions of the rough palmar surfaces of the bones. The **posterior** or **dorsal ligaments**, also three in number, are similarly disposed on the dorsal aspect. The **interosseous ligaments** (Fig. 227) are two or three in number. That which joins os magnum to unciform is the strongest; that between the trapezoid and os magnum is situated towards the dorsal parts of their opposing surfaces; the third, situated between contiguous non-articular surfaces of the trapezium and trapezoid, is always the feeblest, and is frequently absent.

The **transverse carpal articulation** (Fig. 227) is situated between the proximal and distal rows of the carpus. The bones of the proximal row present the following characters on their inferior or distal aspect. The outer part of the articular surface is deeply concave, both in the antero-posterior and in the transverse directions, but the inner part of the same surface is concavo-convex, more especially in the transverse direction.

Superiorly, the articular surfaces of the distal row of carpal bones present an irregular outline. That part pertaining to the trapezium and trapezoid is concave in the antero-posterior and transverse directions, and lies at a considerably lower level than the portion belonging to the os magnum and unciform, which is, moreover, markedly convex in the antero-posterior and transverse directions, with the exception of the innermost part of the unciform, where it is concavo-convex in both of these directions.

This articulation is invested by a complete short **capsule** (Fig. 226) which binds the two rows of the carpus together, and sends prolongations to the investing capsules of the proximal and distal articulations. The ligament as a whole is very strong, and individual bands are not readily defined, although certain special bands may be described. The **palmar ligaments** radiate from the os magnum to the scaphoid, cuneiform, and pisiform. The interval between the os magnum and semilunar is occupied by oblique fibres, some of which pass from scaphoid to cuneiform, while these are joined by others, prolonged obliquely downwards and inwards, from the

radial end of the anterior radio-carpal ligament. By these different bands the palmar aspect of the joint is completely closed.

The **dorsal ligaments** are more feeble than the palmar. They form a thin, loosely-arranged stratum, in which the only noteworthy bands are one which joins the scaphoid to os magnum, and another which joins cuneiform to unciform.

The **external lateral ligament** (lig. collaterale carpi radiale, Fig. 227) extends between contiguous rough areas on the radial aspects of the scaphoid and trapezium. By its margins it is continuous both with the palmar and dorsal ligaments.

The **internal lateral ligament** (lig. collaterale carpi ulnare, Fig. 227) is arranged like the former in regard to its margins, and by its ends it is attached to the contiguous rough ulnar surfaces of the cuneiform and unciform bones.

Both of these lateral ligaments are directly continuous with the corresponding lateral ligaments of the radio-carpal joint.

An **interosseous ligament** (Fig. 227) is occasionally found within the capsule, extending across the joint cavity between the os magnum and the scaphoid.

The **pisi-cuneiform articulation** is an arthroidal diarthrosis. The mutual articular surfaces of the two bones are flattened and circular, and only permit of a small amount of gliding movement.

The joint is provided with a thin but complete **capsule** of fibrous tissue, which is specially strengthened inferiorly by two strong bands, viz. **pisi-unciform** (lig. pisohamatum) and **pisi-metacarpal** (lig. pisometacarpeum, Fig. 226). Both of these bands extend from the lower and inner aspect of the pisiform to adjoining parts of the hook of the unciform and base of the fifth metacarpal bone respectively. To a great extent these ligamentous bands may be regarded as extensions of the insertion of the tendon of the flexor carpi ulnaris muscle which is attached to the upper part of the pisiform bone. Looked at as ligaments, however, they are specially strong to prevent the displacement of the pisiform bone during contraction of the muscle inserted into it.

The **synovial membranes** (Fig. 227) of the carpal joints are two in number. Of these, one is restricted to the pisi-cuneiform articulation, and is correspondingly simple, although occasionally the joint cavity may communicate with that of the radio-carpal joint.

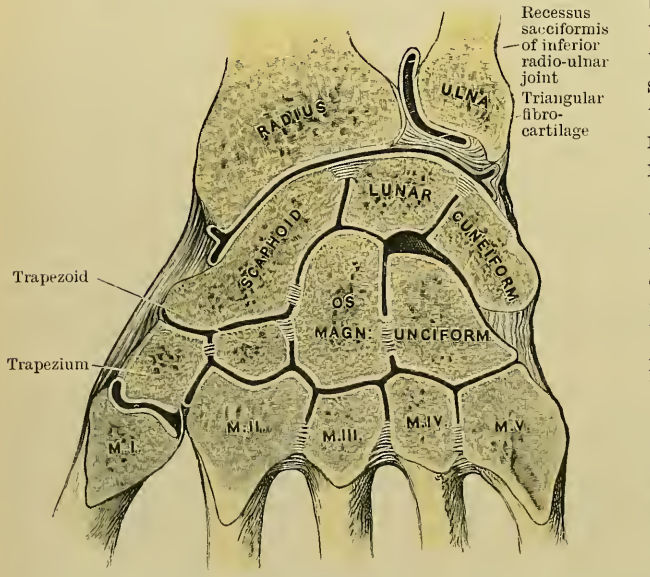


FIG. 227.—CORONAL SECTION through the radio-carpal, carpal, carpo-metacarpal, and intermetacarpal joints, to show joint cavities and interosseous ligaments (diagrammatic).

The other synovial membrane is associated with the transverse carpal joint which extends transversely between the two rows of carpal bones, with prolongations into the vertical intervals between the adjoining bones of each row, *i.e.* the intercarpal articulations. It is, therefore, an elaborate cavity, which may be still further extended, by the absence of interosseous ligaments, so as to reach the radio-carpal and carpo-metacarpal series of joints. The first condition is rare, but the second is not uncommon, and results from the absence of the interosseous ligament between trapezium and trapezoid, or of that between trapezoid and os magnum.

INTERMETACARPAL JOINTS.

The four inner metacarpal bones articulate with each other at their proximal ends or bases, between the opposing surfaces of which joint cavities are found—arthrodial diarthroses. These cavities are continuous with the carpo-metacarpal joint (not yet described), and hence the ligamentous arrangements only enclose three aspects of each joint.

Three strong **transverse ligaments** (Figs. 226 and 227) bind adjacent palmar, dorsal, and interosseous areas of the bases of the metacarpal bones, and hence they are called **ligamenta basium** (oss. metacarp.) **volaria, dorsalia et interossea.** A synovial membrane is associated with each of these joints, but it may be regarded as a prolongation from the carpo-metacarpal articulation.

CARPO-METACARPAL JOINTS.

The articulation of the metacarpal bone of the thumb with the trapezium differs in so many respects from the articulation between the other metacarpal bones and the carpus, that it must be considered separately.

(*A*) The **articulatio carpo-metacarpea pollicis** (Figs. 226 and 227) is the joint between the infero-external surface of the trapezium and the superior surface of the base of the first metacarpal bone. Both of these surfaces are saddle-shaped, and they articulate by mutual co-aptation.

The joint-cavity is surrounded by a fibrous **capsule**, in which we may recognise palmar, dorsal, external, and internal lateral bands, the last being the strongest and most important.

Synovial membrane lines the capsule, and the joint-cavity is isolated and quite separate from the other carpal and carpo-metacarpal articulations.

At this joint movements occur about at least three axes. Thus, around a more or less transverse axis, **flexion** and **extension** take place; in an antero-posterior axis **abduction** and **adduction** (movements which have reference to the middle line of the hand) are found; while a certain amount of **rotation** is possible in the longitudinal axis of the digit. The very characteristic movement of **opposition**, in which the tip of the thumb may be applied to the tips of all the fingers, results from a combination of flexion, adduction, and rotation, and by combining all the movements possible at the various axes a considerable degree of **circumduction** may be produced, in spite of the fact that this is not a ball-and-socket joint.

(*B*) The **articulationes carpo-metacarpeæ digitorum** are the joints between the bases of the four inner metacarpal bones and the four bones of the distal row of the carpus. They are all arthrodial diarthroses, and the opposed articular surfaces present alternate elevations and depressions which form a series of interlocking joints. The joint cavities between the carpal bones of the distal row, and also the more extensive intermetacarpal joint cavities, open into this articulation.

This series of joints is invested by a common capsule which is weakest on its radial side, but is otherwise well defined. Its fibres arrange themselves in small slips, which pass obliquely in different directions, and vary in number for each metacarpal bone. Thus the **oblique palmar ligaments** (ligamenta carpo-metacarpea volaria, Fig. 225) usually consist of one slip for each metacarpal bone, but there may be two slips, and the third metacarpal bone frequently has three, of which one lies obliquely in front of the tendon of the flexor carpi radialis muscle.

The **oblique dorsal ligaments** (ligamenta carpo-metacarpea dorsalia) are similar short bands, of greater strength and clearer definition, by which the index metacarpal is bound to the trapezium and trapezoid; the middle metacarpal to the os magnum, and frequently to the trapezoid; the ring metacarpal to the os magnum and unciform, and the metacarpal of the minimus to the unciform.

Interosseous ligaments, one or sometimes two in number, occur within the capsule. They are usually situated in relation to one or both of the contiguous margins of the bases of the third and fourth metacarpal bones, from which they extend upwards to adjacent margins of the os magnum and unciform. Occasionally they are sufficiently developed to divide the joint cavity into radial and ulnar sections.

The **synovial membrane** (Fig. 227) is usually single and lines the capsule, but, as already explained, it has prolongations into the intermetacarpal and intercarpal series of joints. In connexion with the latter, the frequent absence of the interosseous ligament between the trapezium and trapezoid permits the free communication of this joint-cavity with that of the transverse carpal joint.

METACARPO-PHALANGEAL JOINTS.

In the case of the pollex this joint is constructed on the plan of a ginglymus diarthrosis; the four corresponding joints of the fingers are also diarthroses of a slightly modified ball-and-socket variety. With the exception of the metacarpal bone of the pollex, each metacarpal bone has a somewhat spherical head articulating with a shallow oval cup upon the base of the first phalanx. It is important to note that the articular surface upon the head of each of these metacarpal bones is wider on the palmar aspect and narrower on the dorsal aspect. The articulation in the thumb presents features similar to those of an inter-phalangeal joint.

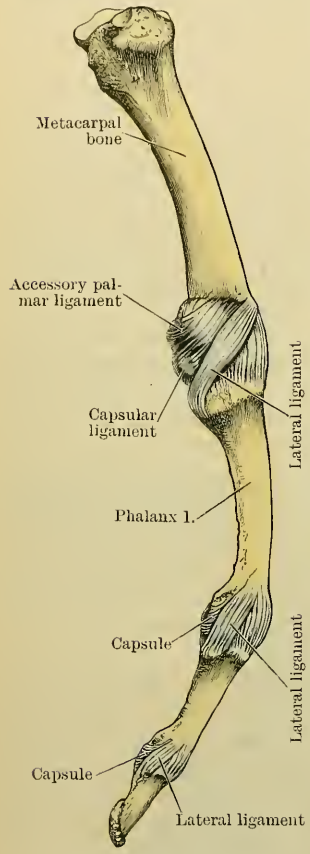


FIG. 228.—METACARPO-PHALANGEAL AND INTERPHALANGEAL JOINTS.

Each joint possesses an articular capsule (Fig. 228) which presents very different degrees of strength in different aspects of the articulation. Thus, on the dorsal aspect, it cannot be demonstrated as an independent structure, but the necessity for dorsal ligaments is to a large extent obviated by the presence of the strong flattened expansions of the extensor tendons.

The **internal** and **external lateral ligaments** (ligamenta collateralia, Fig. 228) are strong cord-like bands which pass from the tubercles and adjacent depressions on the sides of the heads of the metacarpal bones to the contiguous non-articular areas on the bases of the proximal phalanges. They are intimately connected on their anterior aspects with the palmar ligaments.

The **palmar ligaments** consist of thick plates of fibro-cartilage loosely connected to the metacarpal bones, but firmly adherent to the phalanges. They are placed between the lateral ligaments, to both of which they are in each case connected. Each plate is grooved on the palmar surface for the long flexor tendons, whilst on its reverse or joint surface it supports and glides upon the head of the metacarpal bone during flexion and extension of the joint. In the case of the thumb this plate of fibro-cartilage usually develops to sesamoid bones, and in the case of the index finger one such sesamoid nodule is frequently found at the radial side of the plate.

An important accessory ligament is found in connexion with the four inner metacarpo-phalangeal articulations, viz. :—

The **Transverse Metacarpal Ligament.**—This structure binds together the distal extremities of the four inner metacarpal bones. The name is applied to three sets of transverse fibres of great strength which are situated in front of the three inner interosseous spaces. These fibres are continuous with the palmar metacarpo-phalangeal ligaments at their lateral margins.

A **synovial membrane** lines the investing capsule of each joint.

INTERPHALANGEAL JOINTS.

Of these joints there are two for each finger and one for the thumb. They all correspond, in being ginglymus diarthroses in which the trochlear character of their articular surfaces is associated with one axis of movement directed transversely.

In their general arrangement they correspond with each other, and to a large extent with the metacarpo-phalangeal series already described. Each is provided

with a definite **capsule** (Fig. 228), of which the palmar and cord-like lateral portions are well marked, while on the dorsal aspect the extensor tendons act as the chief support. The palmar ligaments are fibrous plates of considerable thickness, and are attached to the two lateral ligaments and to the intervening rough surface on the distal phalanges, while their proximal margins are not attached to bone. Each ligament has its lateral margins prolonged proximally to the adjacent sharply-defined lateral ridges on the phalangeal shafts.

The **lateral ligaments** (Fig. 228) are strong, rounded, short bands, continuous with the preceding, and attached to adjacent non-articular lateral aspects of the phalanges.

Each joint possesses a **synovial membrane** which lines its capsule, but its arrangement presents no special peculiarity.

Movements of the Carpal, Intermetacarpal, Metacarpo-phalangeal and Interphalangeal Joints.

The amount of movement which is possible at individual joints of the intercarpal, intermetacarpal, and carpo-metacarpal series is extremely limited, both on account of the interlocking nature of the articular surfaces and the restraining character of the ligamentous bands. Taken as a whole, however, the movements of the carpus and metacarpus enable the hand to perform many varied and important functions. This is largely due to the greater mobility of those joints on the radial and ulnar borders of the hand, as well as to the general elasticity of the arches formed by the carpus and metacarpus. These conditions particularly favour the movements of opposition and prehension. In the opposite direction, *i.e.* when pressure is applied from the palmar aspect, the metacarpal and carpal arches tend to become flattened, but great elasticity is imparted by the tension of the various ligaments.

The four inner metacarpo-phalangeal joints are ball-and-socket joints, and movements of **palmar-flexion** and **extension** are freely performed about a transverse axis. In exceptional cases a certain amount of **dorsi-flexion** is possible. About an antero-posterior axis movements occur which are usually referred to the middle line of the hand, and hence called **abduction** and **adduction**, but in consequence of the difference in the width of the articular surface on the dorsal and palmar aspects of the heads of the four inner metacarpal bones it is only possible to obtain abduction when the joints are extended, while in the flexed position the joints become locked and abduction is impossible.

The movements of the index finger are less hampered than in the case of the others, but each of them can perform a modified kind of **circumduction**.

The metacarpo-phalangeal joint of the thumb and all the interphalangeal joints are uniaxial or hinge-joints acting about a transverse axis, which permits of **palmar-flexion** and **extension** being freely performed, but **dorsi-flexion** is, as a rule, entirely prevented by the palmar and lateral ligaments.

ARTICULATIONS AND LIGAMENTS OF THE PELVIS.

Although we may consider the pelvis as a separate part of the skeleton, yet it is essential to remember that the bones which enter into its composition belong to the spinal column (sacrum, coccyx) and the lower limb (innominate bone). Accordingly, the articulations, with their corresponding ligaments, may be arranged as follows:—

(*a*) Those by which the segments of the coccyx are joined together (already described, *v.* p. 264);

(*b*) That by which the sacrum articulates with the coccyx (already described, *v.* p. 264);

(*c*) Those by which the sacrum articulates with the last lumbar vertebra (Lumbo-sacral joints);

(*d*) Those by which the innominate bones are attached to the spinal column (Sacro-iliac joints);

(*e*) That by which the innominate bones are attached to each other (Symphysis pubis).

Lumbo-sacral Joints.

The articulation of sacrum with the fifth lumbar vertebra is constructed precisely on the principle of the articulations between two typical vertebræ, and the usual ligaments associated with such joints are repeated. There is, however, an additional accessory ligament, termed the **lateral lumbo-sacral ligament** (Fig. 229).

This extends from the front of the inferior border of the transverse process of the last lumbar vertebra, downwards and slightly outwards, to the front of the lateral aspect of the ala of the sacrum, close to the sacro-iliac joint. Further, a variable membranous band extends between the lateral aspect of the lower part of the body of the last lumbar vertebra and the front of the ala of the sacrum. This band lies in front of the anterior primary division of the fifth lumbar nerve.

SACRO-ILIAC JOINT.

Each innominate bone articulates with the sacral section of the spinal column on each side through the intervention of a diarthrosis, termed the **sacro-iliac joint** (articulatio sacro-iliaca).

This joint is formed between the contiguous auricular surfaces of the sacrum and ilium. Each of these surfaces is more or less completely clothed by hyaline articular cartilage. The joint cavity, which is little more than a capillary interval, may be crossed by fibrous bands.

The joint cavity is surrounded by ligaments of varying thickness and strength,

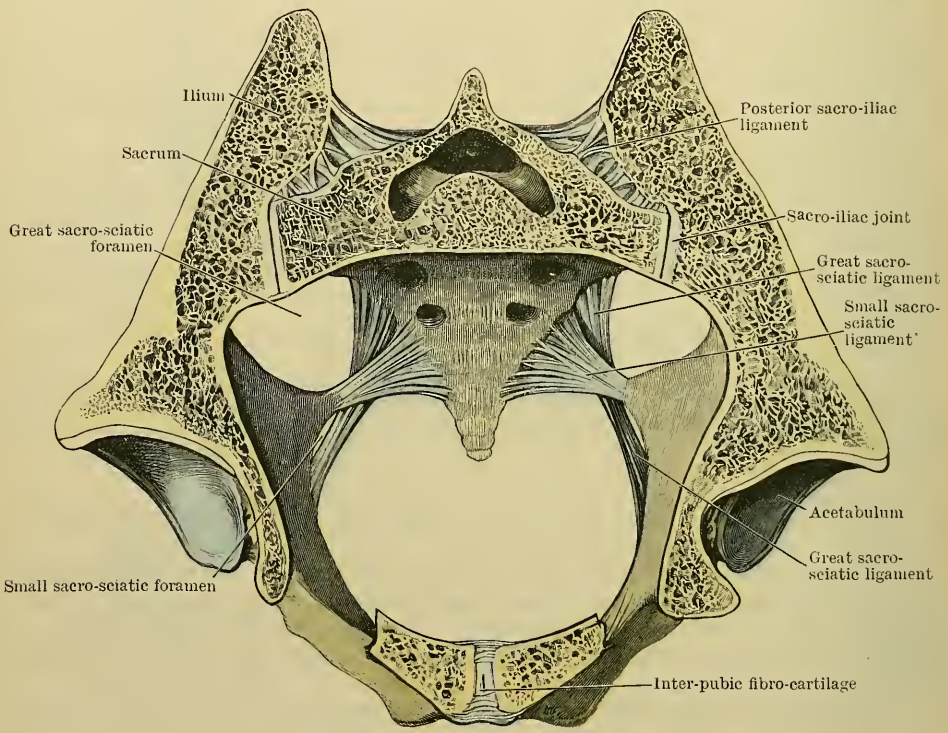


Fig. 229.—Coronal Section of Pelvis.

which constitute its **capsule**. Thus the anterior part of the investing capsule is thin, and consists of short but strong fibres which pass between adjoining surfaces on the ala of the sacrum and the iliac fossa of the innominate bone; they form the **anterior sacro-iliac ligament** (lig. sacro-iliacum anterius, Fig. 229). On the posterior aspect there are two ligaments. The **short posterior sacro-iliac ligament** (lig. sacro-iliacum posterius breve, Fig. 230) consists of numerous strong fasciculi, which pass from the rough area on the inner aspect of the ilium, above and behind its auricular surface, downwards and inwards to the transverse tubercles and the depressions behind the first and second segments of the sacrum. This ligament is of great strength, and with its fellow it is responsible for suspending the sacrum and the weight of the superimposed trunk from the innominate bones.

The **long** or **oblique posterior sacro-iliac ligament** (lig. sacro-iliacum posterius longum, Fig 230) is a superficial thickened portion of the preceding ligament.

It consists of a definite band of fibres passing from the postero-superior iliac spine to the transverse tubercles of the third and fourth segments of the sacrum.

The **synovial cavity** of this joint is very imperfect and rudimentary.

Several accessory ligaments are associated with the articulation of the innominate bone to the sacral section of the spinal column.

The **ilio-lumbar ligament** (lig. ilio-lumbale, Fig. 229), which is merely the

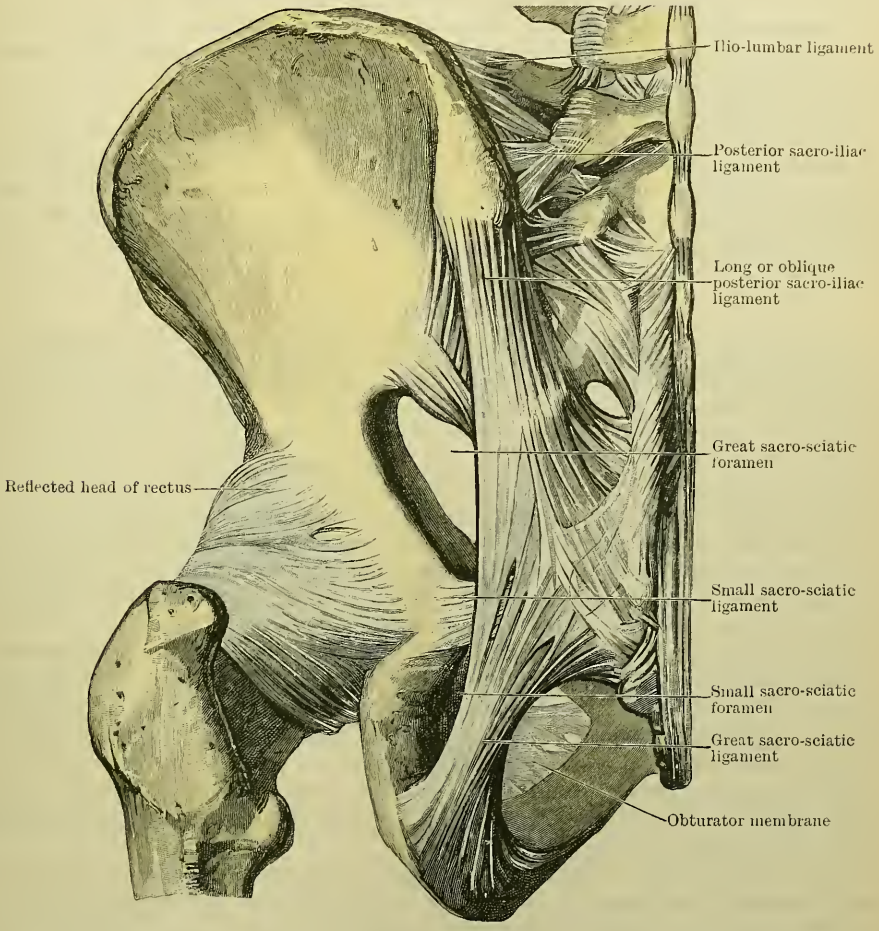


FIG. 230.—POSTERIOR VIEW OF THE PELVIC LIGAMENTS AND OF THE HIP-JOINT.

thickened anterior lamina of the fascia lumborum, extends from the tip of the transverse process of the last lumbar vertebra, almost horizontally outwards, to the inner lip of the iliac crest at a point a short distance behind its highest level. A proportion of these fibres is attached to the inner rough surface of the ilium between the iliac crest and the auricular impression. To these the name of the **lig. ilio-lumbale inferius** is applied.

The **great** or **posterior sacro-sciatic ligament** (lig. sacro-tuberosum, Fig. 230) is somewhat triangular in outline. It occupies the interval between the sacrum and the innominate bone, and is attached mesially to the posterior inferior spine of the ilium; to the posterior aspect of the transverse tubercles and lateral margins of the third, fourth, and fifth segments of the sacrum, as well as to the side of the first segment of the coccyx. It passes downwards and outwards, becoming narrower as it approaches the ischium, near to which, however, it again expands, to be attached to the inner side of the ischial tuberosity, immediately below the groove for the tendon of the obturator internus muscle, *i.e.* the lesser sciatic notch. A continuation of the inner border of the ligament—the **processus**

falciformis (Fig. 230)—runs upwards and forwards on the inner aspect of the ramus of the ischium.

The great sacro-sciatic ligament is believed by many to represent the original or proximal end of the long or ischial head of the biceps flexor cruris muscle.

The **small** or **anterior sacro-sciatic ligament** (lig. sacro-spinosum, Figs. 229 and 230) is situated in front, and in a measure under cover of the great sacro-sciatic ligament. Triangular in form, it is attached by its base to the last two segments of the sacrum and the first segment of the coccyx, and by its pointed apex to the tip and upper aspect of the ischial spine. This ligament is intimately associated with the coccygeus muscle, and by some it is regarded as being derived from it by fibrous transformation of the muscle fasciculi.

By the great and small sacro-sciatic ligaments the two sciatic notches of the innominate bone are converted into foramina. Thus the small sacro-sciatic ligament completes the boundaries of the great sciatic foramen (foramen ischiadicum majus); while the great sacro-sciatic ligament, assisted by the small sacro-sciatic ligament, closes the small sciatic foramen (foramen ischiadicum minus).

SYMPHYSIS PUBIS.

The anterior wall of the osseous pelvis is completed by the articulation of the bodies of the two pubic bones constituting the **symphysis pubis.** This joint conforms in its construction to the general plan of an amphiarthrosis. Thus it is mesial in position; each pubic bone is covered by a layer of hyaline cartilage, which closely adapts itself to the rough tuberculated surface of the pubic bone; while between these two hyaline plates there is an interposed fibro-cartilage (lamina fibro-cartilaginea interpubica), in the interior of which there is usually a vertical antero-posterior cleft. This cavity, which is placed nearer the posterior than the anterior aspect of the joint, does not appear until between the seventh and tenth years, and as it is not lined by a synovial membrane, it is supposed to result from the breaking down of the interpubic lamina.

The **anterior pubic ligament** (lig. pubicum anterius, Fig. 229) is a structure of considerable thickness and strength. Its superficial fibres, which are derived very largely from the tendons and aponeuroses of adjoining muscles, are oblique, and form an interlaced decussation. The deeper fibres are short, and extend transversely from one pubic bone to the other.

The **posterior pubic ligament** (lig. pubicum posterius, Fig. 230) is very weak, and consists of scattered fibres which extend transversely between contiguous pubic surfaces posterior to the articulation.

The **superior pubic ligament** (lig. pubicum superius, Fig. 229) is likewise weak, and consists of transverse fibres passing between the two pubic crests.

The **inferior** or **subpubic ligament** (lig. pubicum inferius vel lig. arcuatum pubis, Fig. 230) occupies the arch of the pubis, and is of considerable strength. It gives roundness to the pubic arch and forms part of the pelvic outlet. It has considerable vertical thickness immediately below the interpubic disc to which it is attached. Laterally it is attached to adjacent sides of the descending rami of the pubis. Its lower border is free, and separated from the triangular ligament of the perineum by a transverse oval interval through which the dorsal vein of the penis passes backwards to the interior of the pelvis.

The Triangular Ligament of the Perineum.

The **triangular ligament of the perineum** is a membranous structure which occupies the pubic arch below and distinct from the subpubic ligament. It assists in completing the pelvic walls anteriorly in the same manner that the obturator membrane does laterally. Indeed, these two structures occupy the same morphological plane. The triangular ligament presents two surfaces—one superficial or perineal; the other deep, or pelvic, and both of these surfaces are associated with muscles. Its lateral borders are attached to the sides of the pubic arch, while its base is somewhat ill-defined, by reason of its fusion with the fascia of Colles in the urethral region of the perineum.

The apex of the triangular ligament is truncated, free, and well defined, constituting the **transverse perineal ligament**, above which there is the interval for the dorsal vein of the penis. It is pierced by a number of vessels and nerves, but the principal opening is situated mesially one inch below the pubic arch, and transmits the urethra.

The Obturator Membrane.

The **obturator membrane** (membrana obturatoria, Fig. 232) occupies the obturator or thyroid foramen. It is attached to the pelvic aspect of the circumference of this foramen. It consists of fibres irregularly arranged and of varying strength, so that sometimes it almost appears fenestrated. At the highest part of the foramen it is incomplete and forms a U-shaped border, between which and the bony circumference of the foramen, the obturator canal (canalis obturatorius) is formed. In this position the membrane is continuous with the parietal pelvic fascia which clothes the inner side of the obturator internus muscle, above the upper free margin of the muscle. From the outer or crural aspect of the membrane some of its fibres are prolonged to the antero-inferior aspect of the capsule of the hip-joint.

Mechanism and Movements of the Pelvis.—The human pelvis presents a mechanism the principal requirement of which is stability and not movement, for, through the pelvis, the weight of the trunk, superimposed upon the sacrum, is transmitted to the lower limbs. Moreover, its stability is largely concerned in the maintenance of the erect attitude. The movements of its various parts are therefore merely such as are consistent with stability, without producing absolute rigidity.

The two innominate bones, being bound together by powerful ligaments at the pubic articulation, constitute an inverted arch, of which the convexity is directed downwards and forwards, while its piers are turned upwards and backwards, and considerably expanded in relation to the hinder parts of the iliac bones. Between the piers of this inverted arch the sacrum is situated. This bone is in no sense a key-stone to an arch, because, as may readily be seen in antero-posterior transverse section, the sacrum is wider in front than behind, and the superposed weight naturally tends to make the sacrum fall towards the pelvic cavity, and so fit less closely between the innominate bones. The sacrum is in reality an oblique platform, in contact with each innominate bone through its articular auricular surfaces, and in this position it is suspended by the posterior sacro-iliac ligaments, and kept securely in place by the "grip" due to the irregularity of the opposed surfaces of the two sacro-iliac articulations. Since the weight of the trunk is transmitted to the anterior and upper end of this sacral platform, there is a natural tendency for the sacrum to revolve upon the transverse axis which passes through its sacro-iliac joints. If this were permitted, the promontory of the sacrum would rotate downwards and forwards towards the pelvic cavity, as really does occur in certain deformities. This revolution or tilting downwards of the forepart of the sacrum is prevented by the action of the great and small sacro-sciatic ligaments, extending from the ischial tuberosity to the hinder and lower end of the suspended platform of the sacrum. Not only so, but these ligaments, acting on a rigid sacrum, tend to hold up the weight upon the sacral promontory.

The various ligaments passing between the last lumbar vertebra and the sacrum and ilium retain the weight of the trunk in position upon the anterior end of the sacrum, and resist its tendency to slip forwards and downwards towards the pelvic cavity. The entire weight of the trunk and pelvis is transmitted to the heads of the thigh bones in the most advantageous position, both for effectiveness and the strengthening of the inverted innominate arch, for it will be evident that the heads of the femora thrust inwards upon the convex side of the arch, very much at the place where the arches are weakest, viz. at the springing of the arch from its piers. The forces which tend to cause movement of the pelvic bones during parturition act from within the pelvis, and have for their object the increase of the various pelvic diameters, in order that the fœtal head may more readily be transmitted. For this purpose the wedge-like dorsal surface of the sacrum is driven backwards, and a certain amount of extra space may thereby be obtained. An important factor, however, in the increase of the pelvic capacity at this period is found in the relaxation of its various ligaments.

THE ARTICULATIONS OF THE LOWER EXTREMITY.

THE HIP-JOINT.

The human body provides no more perfect example of an enarthrodial diarthrosis than the hip-joint (articulatio coxæ). Combined with all that variety of movement which characterises a multi-axial joint, it nevertheless presents great stability, which has been obtained by simple arrangements, for restricting the range of its natural

movements. This stability is of paramount importance for the maintenance of the erect attitude, and the mechanical adaptations whereby this result is obtained are such that the erect attitude may be preserved without any great degree of sustained muscular effort.

Articular Surfaces.—The head of the femur is globular in shape, and considerably exceeds a hemisphere. It is clothed by hyaline articular cartilage on those parts which come into direct contact with the acetabulum. There is frequently more or less of extension of the articular cartilage from the head to the adjoining anterior part of the neck, an extension which is accounted for by the close and constant apposition of this portion of the neck with the hinder aspect of the ilio-femoral ligament. The limit of the articular cartilage covering the head is indicated by a sinuous border. Further, there is an absence of articular cartilage from the pit or depression on the head of the femur.

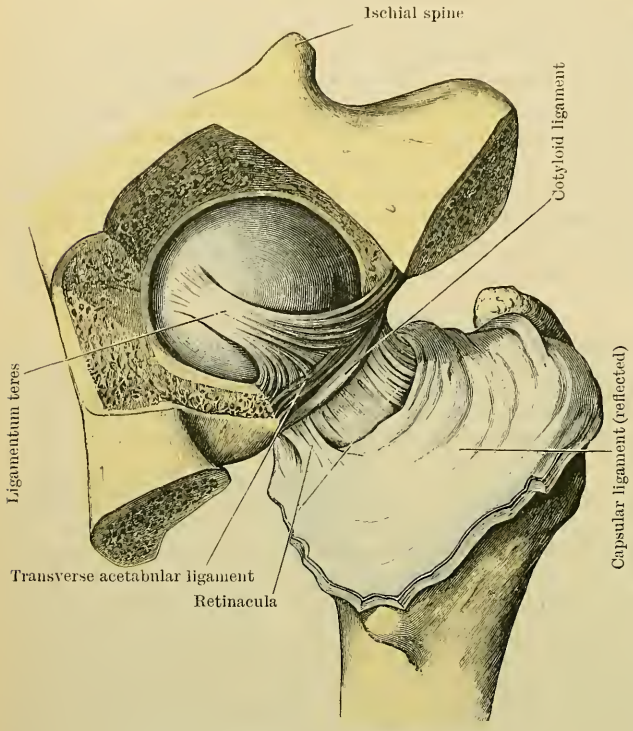


Fig. 231.—Dissection of the Hip-Joint.
Bottom of the acetabulum removed, and capsule of the joint thrown outwards towards the trochanters.

The acetabulum is a deep cup-shaped cavity which presents an interruption or notch on its antero-inferior margin. The interior of the cup is lined by a ribbon-like band of articular cartilage which extends to the brim of the cavity, but does not cover the floor of the cup. This articular ribbon-shaped band is widest on its supero-posterior aspect, and narrowest at the anterior margin of the notch.

The **transverse ligament** (lig. transversum acetabuli, Fig. 231) bridges the acetabular notch, and consists of strong transverse fibres which are attached to both of its margins, but more extensively to the postero-inferior. This ligament does not entirely fill the notch, but leaves an open interval between its lower border and the bottom of the notch through which vessels and nerves enter the cup. The acetabular aspect of this ligament constitutes an articular surface.

The acetabulum is deepened by the **cotyloid ligament** (labrum glenoidale, Figs. 231 and 232), which consists of a strong ring of fibro-cartilaginous tissue attached to the entire rim of the cup. The attached surface of the ring is broader than its free edge, and, moreover, the latter is somewhat contracted, so that the ligament grasps the head of the femur which it encircles. Its fibres are partly oblique and partly circular in their direction. By the former it is firmly implanted on the rim of the acetabulum and the transverse ligament of the notch; by the latter the depth of the cup is increased through the elevation of its edge, and its mouth slightly narrowed. By one surface this ligament is also articular.

A **capsule** (capsula articularis, Figs. 230 and 232) completely invests the joint cavity. This is a fibrous membrane of great strength, although it is not of equal thickness throughout, being considerably thicker on the supero-anterior aspect than at any other part. Unlike the corresponding structure of the shoulder-joint, it does not permit of the withdrawal of the head of the femur from contact with the acetabular articular surfaces, except to a very limited extent. Its fibres are arranged

both in the circular and in the longitudinal direction, the former, known as the **zona orbicularis**, being best marked posteriorly, while the longitudinal fibres stand out more distinctly in front, where they constitute special ligaments. Looked at as a whole, the capsule has the following attachments: *superiorly* it surrounds the acetabulum, on the upper and hinder aspects of which it is attached directly to the innominate bone, while on the front and lower aspects it is attached to the non-articular surfaces of the cotyloid and transverse ligaments; *inferiorly* it encircles the neck of the femur, where it is attached in front to the anterior intertrochanteric line; above, to the inner aspect of the root of the great trochanter; below, to the lower part of the neck of the femur, in close proximity to the small trochanter; behind, to the line of junction of the outer and middle thirds of the neck of the femur. It is a matter of some importance to note that only part of the posterior surface of the neck of the femur is enclosed within the capsule. The femoral attachments of the capsule vary considerably in their strength, being particularly firm above and in front, but much weaker below and behind, where the orbicular fibres are well seen. Many fibres of the capsule are reflected from its deep aspect upwards upon the neck of the femur, where they form ridges, and to these the term **rectinacula** (Fig. 231) is applied.

The longitudinal fibres of the capsule are arranged so as to form certain definite bands, viz:—

(1) The **ilio-femoral ligament** (lig. ilio-femorale, Fig. 232) consists of a triangular set of fibres attached above, by their apex, to the lower part of the anterior inferior iliac spine and the immediately adjoining part of the rim of the acetabulum, and below, by their base, to the anterior intertrochanteric line of the femur. This ligament is the thickest part of the capsule, but its sides are more pronounced than its centre, especially towards its base. Consequently the ilio-femoral band presents some resemblance to an inverted Y (ʎ), and therefore it is very generally known as the Y-shaped ligament of Bigelow.

The outer or upper limb of the ilio-femoral ligament may be somewhat extended by the inclusion of additional longitudinal fibres, and described as the **ilio-trochanteric** ligament (lig. ilio-trochantericum). This band arises from the anterior part of the dorsum of the acetabulum, and extends to the femoral neck, close to the anterior end of the inner surface of the great trochanter.

(2) The **pubo-femoral** or **pubo-capsular ligament** (lig. pubo-femorale v. pubo-capsulare, Fig. 232) is composed of some bands of fibres of no great strength, which extend from the outer end of the horizontal ramus of the pubis, the ilio-pectineal eminence, the obturator crest and the obturator membrane, to lose themselves for the most part in the capsule, although a certain proportion of them may be traced to the inferior aspect of the femoral neck, where they adjoin the lower attachment of the Y-shaped ligament.

(3) The **ischio-capsular ligament** (lig. ischio-capsulare, Fig. 230) consists of a broad band of short, fairly strong longitudinal fibres, which, by their upper ends, are attached to the ischium between the small sciatic notch and the obturator foramen, while their lower ends become merged in the zona orbicularis of the general capsule.

Within the capsule, and quite distinct from it, there are the ligamentum teres and the Haversian gland.

The **interarticular ligament** (lig. teres femoris, Fig. 231) is a strong, somewhat flattened band of fibrous tissue, attached by one end to the upper half of the pit or depression on the head of the femur. By its inner end it is attached to the lower edge of the articular surface of the transverse ligament, with extensions to the opposite borders of the acetabular notch, but chiefly to the hinder or ischial border. This ligament varies very greatly in its strength and development in different subjects, and in certain rare cases it is absent.

The so-called **Haversian gland** occupies the bottom or non-articular area of the acetabulum. It consists of a mass of fat covered by synovial membrane. This pad of fat is continuous with the extra-capsular fat through the passage subjacent to the transverse ligament of the notch.

A **synovial membrane** lines the capsule from which it is reflected to the neck of the femur along a line which corresponds to the femoral attachments of the

capsule. Thus the synovial membrane clothes more of the femoral neck anteriorly than in any other position. Posteriorly, where the capsule is feebly attached to the neck of the femur, the synovial membrane may be seen from the outside of the capsule. The synovial membrane extends close up to the articular margin of the head of the femur, and on the upper and lower aspects of the neck it is gathered into loose folds upon the retinacula. These folds or plications are best marked along the line of synovial reflection, and do not reach as far as the femoral head. At its acetabular end the synovial membrane is prolonged from the inside of the capsule to the outer non-articular surface of the cotyloid and transverse ligaments, upon which it is continued as a lining for their acetabular or articular surfaces, and further, it provides a covering for the fat at the bottom of the acetabular fossa, as well as a complete tubular investment for the ligamentum teres.

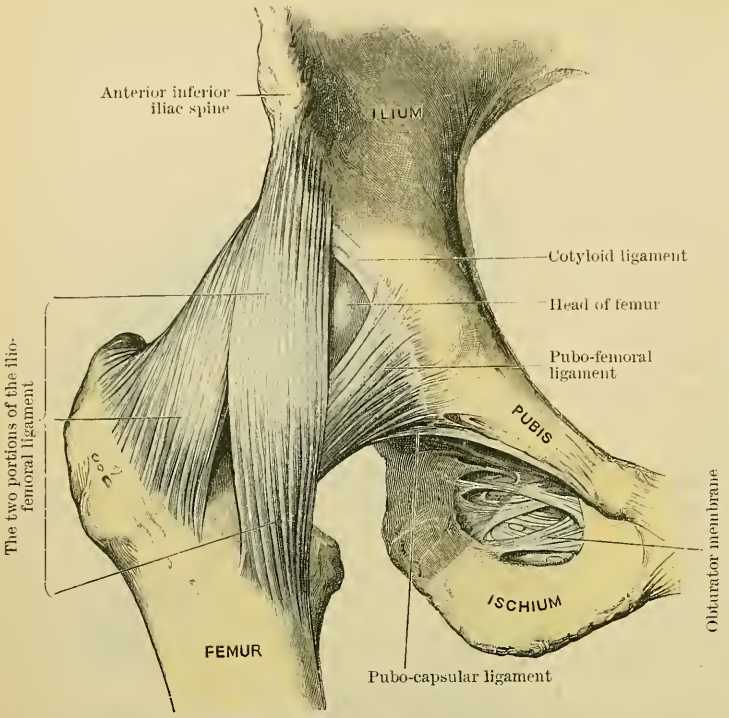


FIG. 232.—DISSECTION OF THE HIP-JOINT FROM THE FRONT.

Occasionally the **synovial bursa**, which is subjacent to the tendon of the ilio-psoas muscle, communicates with the interior of the hip-joint through an opening in the anterior wall of the capsule (Fig. 232), situated between the pubo-femoral ligament and the inner or lower limb of the ilio-femoral ligament.

Movements at the Hip-Joint.—The movements which occur at the hip-joint are those of a multiaxial joint. These are **flexion, extension, abduction, adduction, rotation,** and **circumduction.** The range of each of these movements is less extensive than in the case of the shoulder-joint, because, at the hip, the freedom of movement is subordinated to that stability which is essential alike for the maintenance of the erect attitude and for locomotion. When standing at rest in the erect attitude the hip-joint occupies the position of **extension,** and as the weight of the trunk is transmitted in a perpendicular which falls behind the centres of the hip-joints, both the erect attitude and the extended position are maintained to a large extent mechanically, without sustained muscular action, by means of the tension of the ilio-femoral ligament. Moreover, the tension of this ligament is sustained by the pressure of the front of the head and neck of the femur against its synovial surface. In this association of parts it is important to note that the articular cartilage of the femoral head may be, and in certain races is, prolonged to the front of the femoral neck; and further, that the constant friction does not destroy the synovial lining of the capsule. Again, the same mechanism which preserves the erect attitude prevents an excessive degree of extension or dorsiflexion. In movement forwards, *i.e.* ventral **flexion,** the front of the thigh is approximated to the anterior abdominal wall. The amount of this movement depends upon the position of the knee-joint, because when the latter is flexed the thigh may be brought into contact with the abdominal wall, whereas when the knee-joint is straightened (*i.e.* extended) the tension of the hamstring muscles greatly restricts the amount of flexion at the hip-joint. **Abduction** and **adduction** are likewise much more restricted than at the shoulder-joint. **Abduction** is brought to a close by the tension of the pubo-femoral band and the lower part of the capsule, and, in addition, the upper aspect of the neck of the femur locks against the margin of the acetabulum. Excessive **adduction** is prevented by the tension of the upper band of the ilio-femoral ligament and the upper part of the capsule. **Rotation** or movement in a longitudinal axis may be either inwards, *i.e.* towards the front, or outwards, *i.e.* toward the back.

In the former the movement is brought to a close by the tension of the ischio-capsular ligament and back part of the capsule, aided by the muscles on the back of the joint; in the latter—rotation outwards—the chief restraining factor is the outer or upper limb of the ilio-femoral ligament. The total amount of rotation is probably less than 60°.

Circumduction is only slightly less free than at the shoulder, but it is complicated by the preservation of the balance upon one foot.

The value and influence of the ligamentum teres are not easily estimated, because it may be absent without causing any known interference with the usefulness of the joint. In the erect attitude this ligament lies lax between the lower part of the femoral head and the acetabular fat. In the act of walking it is rendered tense at the moment when the pelvis is balanced on the summit of the supporting femur. Analysis of this position shows the femur to be adducted, with probably, in addition, a small amount of flexion (*i.e.* bending forwards) and internal rotation. Again, this ligament is said to be tense when the thigh is rotated outwards. The equivalent of this movement is doubtless found in the rotation of the pelvis, which occurs in the act of walking at the moment of transition from the toe of the supporting foot to the heel of the advancing foot. The interest connected with this ligament is perhaps morphological rather than physiological. It is believed by some to represent the tendon of a muscle which in birds occupies a position external to the joint capsule.

THE KNEE-JOINT.

The knee-joint (articulatio genu) is the largest articulation in the body, and its structure is of a very elaborate nature. The part it plays in maintaining the erect attitude materially influences its construction, and special arrangements are provided for the mechanical retention of the joint in the extended position, in view of the fact that the line of gravity falls in front of the centre of the articulation. Its principal axis of movement is in the transverse direction, consequently it belongs to the ginglymus or hinge variety of the diarthroses. At the same time a slight amount of rotation of the tibia in its long axis is permitted during extreme flexion; but while this fact is of considerable importance in the study of certain accidents to which the joint is liable, as well as in the study of its comparative morphology, it is not sufficiently pronounced to interfere with its classification as a hinge-joint.

Articular surfaces pertaining to the femur, tibia, and patella, enter into the formation of the knee-joint. The articular surface of the femur extends over a large part of both condyles, and may be divided into patellar and tibial portions by faintly-marked, almost transverse grooves, which pass across the articular surface immediately in front of the intercondylar notch. As a rule marginal indentations of the articular surface render the positions of these transverse grooves more distinct.

The **patellar portion** (Fig. 233) is situated anteriorly, and is common to both condyles, although developed to a larger extent in association with the outer condyle, on which it ascends to a higher level than on the inner condyle. This surface is trochlear, and forms a vertical groove bordered by prominent lateral borders.

The **tibial portion** of the articular surface of the femur is divided into two articular areas, in relation to the inferior aspects of the two condyles, by the wide non-articular intercondyloid notch. These two surfaces are for the most part parallel, but in front the internal tibial surface turns obliquely outwards as it passes into continuity with the patellar trochlea, while posteriorly, under certain circumstances, *e.g.* the squatting posture, the articular surface of the inner condyle may extend to the adjoining portion of the popliteal area of the bone.

When the joint is in the position of extreme flexion, the patella is brought into direct contact with that part of the articular surface on the inner condyle which bounds the intercondyloid notch upon its inner and anterior aspects. This relationship is indicated by the presence of a distinct semilunar facet on the cartilage in that situation (Fig. 233). The articular surface of the femur may therefore be regarded as presenting **femoro-patellar** and **femoro-tibial areas.**

The **patella** presents on its posterior aspect a transversely-elongated oval articular facet and an inferior rough, triangular, non-articular area. The articular facet is divided into two principal lateral portions by a prominent rounded vertical ridge. Of these the outer is the wider. A less pronounced and nearly vertical ridge marks off an additional facet called the internal perpendicular facet, close to the inner margin of the articular surface. Two faint transverse ridges cut off

narrow upper and lower facets from the general articular surface without encroaching on the narrow innermost vertical facet (Goodsir) (Fig. 233).

The head of the **tibia** presents on its superior aspect two condylar articular surfaces, separated from each other by a non-articular antero-posterior area, which is wider in front and behind than in the middle, where it is elevated to form a bifid tibial spine.

The **external condylar facet** is slightly concavo-convex from before backwards, and slightly concave transversely. This surface is almost circular, and extends to the free external border of the tibial head, where it is somewhat flattened. Posteriorly the articular surface is prolonged downwards on the tuberosity in relation to the position occupied by the tendon of the popliteus muscle. The

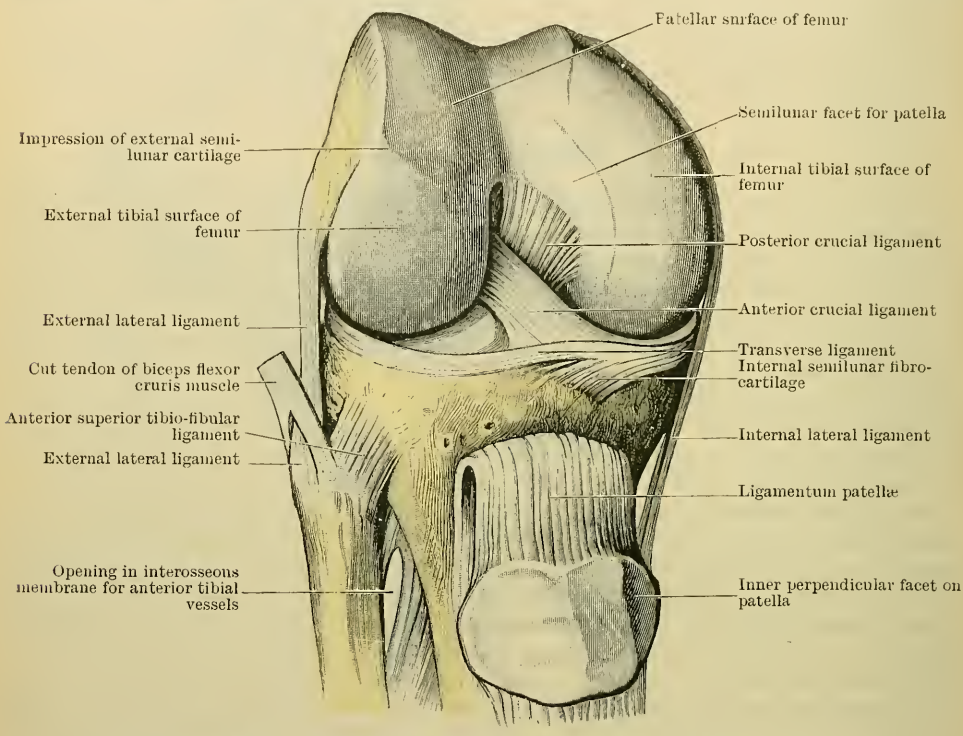


FIG. 233.—DISSECTION OF THE KNEE-JOINT FROM THE FRONT: PATELLA THROWN DOWN.

internal condylar facet is oval in outline, and distinctly concave both in its antero-posterior and transverse diameters.

Ligaments.—Like all diarthroses, this joint is invested by an envelope or **capsule** (capsula articularis), which does not, however, entirely surround the joint cavity, for it is absent as a fibrous membrane above the joint cavity, subjacent to the tendon of the quadriceps extensor muscle. Its specially named bands are not of themselves sufficient to form a complete investment, and a capsular membrane, which largely consists of augmentations from the fascia lata and the tendons of surrounding muscles, supplies the defective areas. Thus, anteriorly, on each side of the patella and the ligamentum patellæ, expansions of the vasti tendons and fascia lata, constituting **lateral patellar ligaments**, are evident. On the outer side of the joint the external lateral ligament is hidden within a covering derived from the ilio-tibial band of the fascia lata. On the inner side expansions from the tendons of the sartorius and semi-membranosus muscles augment the capsule, which here becomes continuous with the internal lateral ligament. Posteriorly the capsule also receives augmentation from the tendon of the semi-membranosus muscle, but it is very thin subjacent to the origins of the gastrocnemius muscle, where it covers the hinder parts of the condyles. Not unfrequently the capsule presents an opening of communication between the interior of the joint cavity and a bursa which lies under cover of the inner head of the gastrocnemius muscle.

The **anterior ligament** (lig. patellæ, Fig. 233), also called the ligamentum patellæ, is a powerful flattened band, attached superiorly to the apex and adjoining margins of the patella, and inferiorly to the rough anterior tuberosity at the upper end of the shaft of the tibia. This ligament also serves as a tendon of insertion for the quadriceps extensor muscle, and a certain number of the fibres of the tendon may be observed to descend as a thin fibrous covering for the anterior surface of the patella. The deep surface of the tendon is separated from the front of the head of the tibia by a synovial bursa, and above this it rests upon the infrapatellar pad of fat, which is placed between the tendon and the synovial membrane of the joint.

The **posterior ligament** (Fig. 234) is a compound structure of unequal strength,

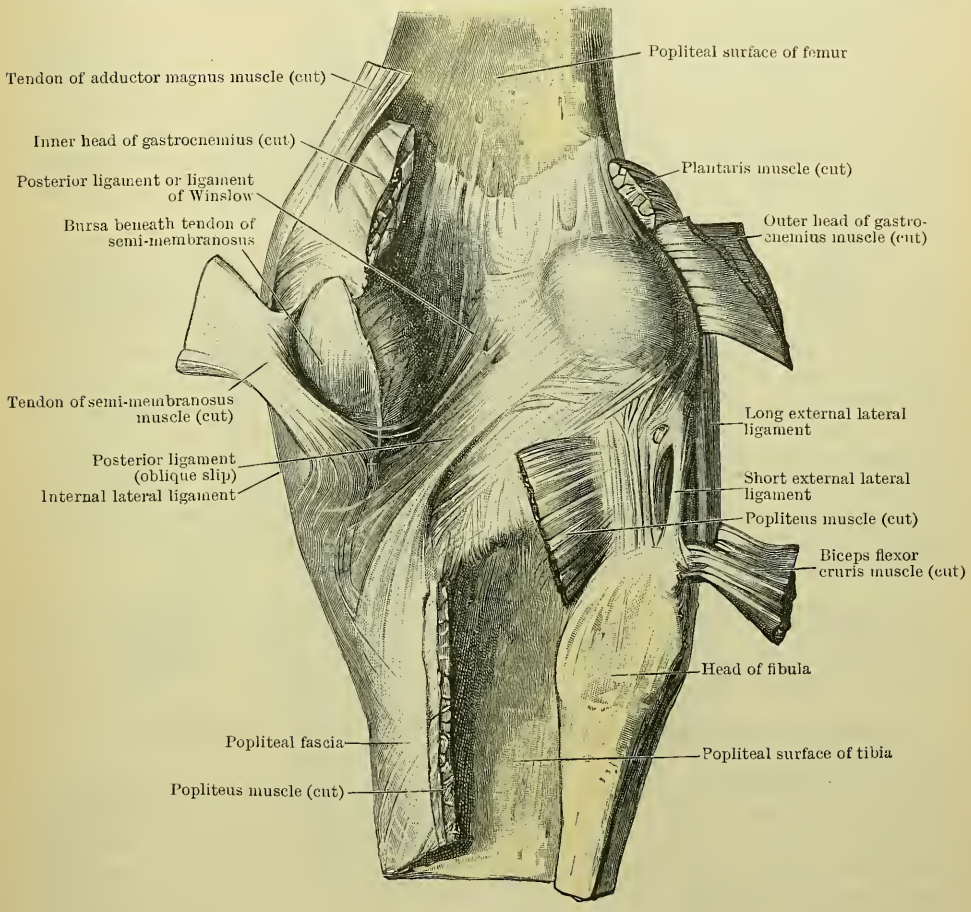


Fig. 234.—The Knee-Joint. Posterior View.

and those portions by which it establishes continuity with the lateral parts of the capsule are remarkably thin. It is attached superiorly to the popliteal surface of the femur, close to the intercondyloid notch, with lateral extensions to the non-articular areas immediately above the posterior articular margins of the two condyles, where it is closely associated with the origins of the gastrocnemius muscle.

Inferiorly it is attached to the rough non-articular posterior border of the head of the tibia, where, to its fibular side, it presents an opening of exit for the tendon of the popliteus muscle (Fig. 234).

The tendon of insertion of the semi-membranosus muscle contributes an important expansion which augments the posterior ligament on its superficial aspect. This expansion—**ligamentum posticum Winslowii**—passes obliquely upwards and outwards to lose itself in the general ligament, but it is most distinct in the region between the femoral condyles, where it may present upper and lower arcuate

borders. A number of vessels and nerves perforate this ligament, and hence it presents a number of apertures.

The **internal lateral ligament** (lig. collaterale tibiale, Figs. 233 and 235) is a well-defined, strong, flat band which is applied to the inner side of the knee-joint, and is rather wider in the middle than at either end. It is frequently regarded as consisting of two portions—an anterior or long portion, and a posterior or short one. The two parts arise close together from the non-articular inner surface of the inner condyle, immediately below the adductor tubercle. The **short** or **posterior portion** descends slightly backwards, to be attached to the postero-internal aspect of the inner part of the tibia above the groove for the semi-membranosus tendon. The **long** or **anterior portion** inclines somewhat forwards, and descending superficially to the tendon of the semi-membranosus, it is continued downwards, to be attached to the upper part of the inner surface of the shaft of the tibia below the level of the anterior tuberosity.

On its superficial aspect the internal lateral ligament is augmented by prolongations from the tendons of the semi-membranosus and sartorius muscles, but is separated by a bursa from the tendons of adductor-gracilis, semi-tendinosus, and sartorius. Its deep surface is adherent to the convex edge of the internal semilunar cartilage, but lower down the inferior internal articular vessels intervene between the ligament and the shaft of the tibia.

The **external lateral ligament** (lig. collaterale fibulare, Figs. 233 and 235), sometimes called the ligamentum laterale externum longum, is a distinct rounded band which is under cover of the ordinary capsule, and yet well separated from the joint cavity by intervening objects. It is attached superiorly to a tubercle on the outer surface of the external condyle, immediately above the groove occupied by the tendon of the popliteus muscle, superficial to which the ligament descends. By its lower end it is attached to the outer side of the head of the fibula, in front of the styloid process. In its course vertically downwards it splits the tendon of insertion of the biceps flexor cruris (Fig. 233), the portions of which are fixed to the head of the fibula on either side of the ligament, and a bursa may intervene between the tendon and the ligament. The inferior external articular vessels pass forwards subjacent to this ligament and above the head of the fibula. Unlike the internal ligament, it is not attached to the corresponding semilunar cartilage.

The **ligamentum laterale externum breve seu posticum** (Fig. 234) is an inconstant structure which is attached by its upper end immediately behind the preceding, and subjacent to the outer head of the gastrocnemius muscle. It likewise descends superficial to the popliteal tendon, and is affixed inferiorly into the styloid process of the fibula.

The **intra-articular structures** of the knee-joint are more important and more numerous than in any other joint of the body.

The **crucial ligaments** (ligamenta cruciata genu) are two strong, rounded, tendinous bands, which extend from the non-articular area on the upper surface of the head of the tibia to the non-articular sides of the intercondyloid notch of the femur. These interarticular ligaments are distinguished from each other as the anterior or external and the posterior or internal. They cross each other like the limbs of an X, yet they remain distinct throughout, and each has its own partial synovial covering. They lie within the capsule of the joint, and extend between non-articular surfaces in relation to the longitudinal axis of the limb.

The **ligamentum cruciatum anterius** (Figs. 233, 235, and 236) is attached inferiorly to the inner part of the rough, depressed area in front of and close to the spine of the tibia. It passes obliquely upwards, outwards, and backwards to the inner non-articular surface of the external condyle, where it finds attachment far back in the posterior part of the intercondyloid notch. This ligament is tense in the position of extension, and therefore it assists in maintaining the erect attitude.

The **ligamentum cruciatum posterius** (Figs. 233, 235, and 236) is somewhat shorter than the preceding. It is attached inferiorly to the hinder part of the depressed surface behind the spine of the tibia and close to the popliteal notch. Its fibres pass obliquely upwards, forwards, and inwards, to be inserted into the outer non-articular surface of the inner condyle, far forwards towards the anterior margin of the intercondyloid notch. It is rendered tense in the position of flexion.

The **semilunar interarticular fibro-cartilages** are two in number—an inner and an outer—placed horizontally between the articular surfaces of the femur and tibia. In general outline they correspond to the circumferential portions of the tibial facets upon which they rest. Each has a thick, convex, fixed border in relation to the periphery of the joint, and a thin, concave, free border directed towards the interior of the joint. Neither of them is sufficiently large to cover the whole of the tibial articular surface upon which it rests. The upper and lower surfaces of each semilune are smooth and free, and each cartilage terminates in an anterior and a posterior fibrous horn or cornu.

The **internal semilunar fibro-cartilage** (meniscus medialis, Figs. 235 and 236)

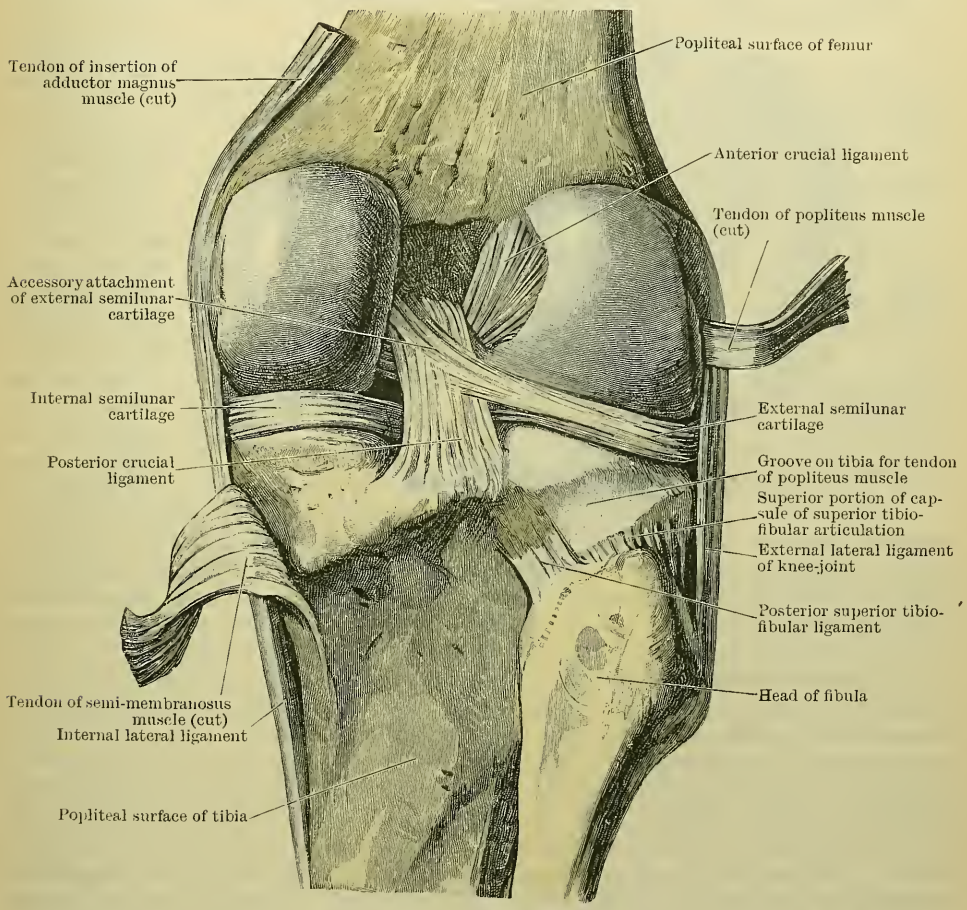


Fig. 235.—The Knee-Joint opened from Behind by the Removal of the Posterior Ligament.

forms very nearly a semicircle. It is attached by its anterior horn to the non-articular surface on the head of the tibia, in front of the tibial attachment of the anterior crucial ligament, and by its posterior horn to the non-articular surface immediately in front of the tibial attachment of the posterior crucial ligament. The deep or hinder part of the internal lateral ligament is attached to its periphery.

The **external semilunar fibro-cartilage** (meniscus lateralis, Figs. 235 and 236) is attached by its anterior horn to the non-articular surface of the tibia in front of the tibial spine, where it is placed to the outer side, and partly under cover of the tibial end of the anterior crucial ligament. By its posterior horn it is attached to the interval between the two tubercles which surmount the tibial spine, *i.e.* in front of the attachment of the posterior horn of the internal semilunar cartilage. This fibro-cartilage, with its two horns, therefore forms almost a complete circle. Posteriorly it is attached by its periphery to the posterior ligament, but on the outer side it

is separated from the external lateral ligament by the tendon of the popliteus muscle, and on this aspect its periphery is free.

The two horns of the external semilune are embraced by the two horns of the internal one, and, while the anterior crucial ligament has its tibial attachment almost between the anterior horns of the two semilunes, the tibial attachment of the posterior crucial ligament is situated behind the posterior horns of the two semilunes.

Both semilunes possess certain accessory attachments. Thus the external semilune sends a large bundle of fibres from its convex posterior border to augment the posterior aspect of the posterior crucial ligament, by which these fibres are conducted to the femur. Again, the convex or peripheral margins of each semilune possess certain attachments to the deep surface of the capsule on its inner and posterior aspects, as has already been explained, but, in addition, they are attached to the non-articular circumference of the tibial head by short fibrous bands known as the **ligamenta coronaria**. Lastly, a rounded band which varies in strength, the **transverse ligament** (lig. transversum genu, Figs. 233 and 236), stretches between the anterior convex margins of the two semilunes, crossing the front part of the non-articular area on the tibial head in its course.

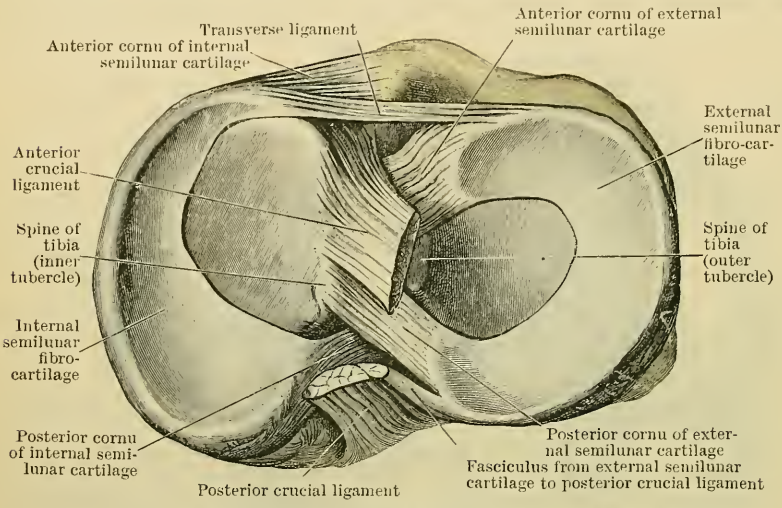


FIG. 236.—UPPER END OF TIBIA WITH SEMILUNAR CARTILAGES AND ATTACHED PORTIONS OF CRUCIAL LIGAMENTS.

The **synovial membrane** of the knee-joint is not only the largest, but the most elaborately arranged of its kind in the body. It not only lines the capsule, but it forms a more or less extensive covering for the intracapsular ligaments and the free surface of the **infra-patellar pad of fat**. This pad acts as a wedge which fits into the interval between the patella, tibia, and femoral condyles, and the synovial membrane upon its surface forms a band or fold which extends from below the level of the patellar articular surface to the anterior part of the intercondyloid notch. This is in no sense a ligament, although it is named the **ligamentum mucosum**, or plica synovialis patellaris. At its femoral end it is narrow and attenuated, but at its patellar end it expands laterally to form wing-like fringes or membranes—the **alar ligaments** (plicæ alares)—which are often distinguished from each other as the inner (plica aliformis medialis) and the outer (plica aliformis lateralis). These folds are more or less loaded with fat.

Apart from these special foldings, the synovial membrane lines the deep surface of the common extensor tendon, and extends upwards for a variable distance above the patella. This extension of the joint cavity almost always communicates with a large bursa situated still higher on the front of the femur. Tracing the synovial membrane downwards, it will be found to cover both surfaces of the semilunar fibro-cartilages. The peripheral or convex margins of these cartilages are only covered by this membrane where they are unattached to the capsule. A prolongation invests the intracapsular portion of the tendon of the popliteus muscle, and separates this tendon from the back part of the tibial head, besides intervening between the external semilune and the head of the tibia.

From the back part of the joint cavity the synovial membrane extends forwards,

and provides a partial covering for the crucial ligaments between which a bursa may be found.

This somewhat complicated arrangement of the synovial membrane may be readily comprehended if it be borne in mind that it really represents the fusion of three separate synovial cavities, which in some animals are permanently distinct. These are indicated in the two femoro-tibial and the single femoro-patellar parts of the articulation.

The joint cavity may communicate with **bursæ** situated in relation to the inner head of the gastrocnemius muscle and the tendon of the semi-membranosus muscle, besides the large supra-patellar bursa already described. Lastly, there may be intercommunication between this joint cavity and that of the superior tibio-fibular articulation.

Movements at the Knee-Joint.—In studying the movements which may occur at the human knee-joint, it is necessary to bear in mind that the lower limb of man is primarily required for purposes of support and locomotion. The principal requirement of the former function is stability accompanied by rigidity, whereas in the latter function the special desideratum is regulated and controlled mobility. Thus, in the same joint, two entirely opposite conditions have to be provided. The stable conditions of support are chiefly concerned in the maintenance of the erect attitude, and the mechanism associated therewith does not call for the exertion of a large degree of sustained muscular effort.

In standing erect the attitude of the limb is that of extension, which mainly concerns the femoro-tibial parts of the joint. In this position the force of gravity acts along a vertical line which falls in front of the transverse axis of the joint, and therefore any tendency to flexion, *i.e.* bending backwards, is mechanically counteracted by the application of a force which tends to produce bending forwards (so-called over-extension). This, however, is absolutely prohibited in normal states of the joint, by the tension of the posterior and lateral ligaments aided by the anterior crucial ligament. The value of this fact may be seen by observing the effect produced by giving the joint a sudden push from behind, which causes an immediate reversal of the positions of the transverse and vertical axes, whereby the body weight at once produces flexion of the joint.

The semilunar cartilages and the infra-patellar pad of fat also assist in maintaining extension, by reason of their close adaptation to, and packing round the condyles as these rest upon the tibia. The anterior margin of the intercondyloid fossa is also brought into contact with the front of the anterior crucial ligament.

In the position of extension the patella is retained at a high level in relation to the trochlear surface of the femur, so that the lower articular facets of the patella are in contact with the trochlea.

During locomotion the movements of the knee-joint are somewhat intricate, for both the femoro-tibial and the femoro-patellar sections of the joint are brought into action. The principal movement which results is flexion, with which there is associated, both at its beginning and ending, a certain amount of screw movement or rotation. Flexion and rotation occur at the femoro-tibial sections of the joint, whereas the movement at the femoro-patellar portion produces a regulating and controlling influence upon flexion.

Taking these factors separately, we observe that each condyle adapts itself to a shallow cup formed by the head of the tibia and the corresponding semilunar cartilage, and as the two condyles move simultaneously and parallel to each other, there is more than the characteristic hinge-joint action, for each condyle glides and rolls in its cup "like a wheel restrained by a drag" (Goodsir) when the movement of bending occurs. Thus the different parts of the condyles are successively brought into relation with the transverse axis of the joint while it passes from extension to flexion and *vice versa*. From the fact that the internal condyle is longer than the external, it is believed that extension is completed by a movement of rotation whereby the joint becomes locked, and the anterior crucial, the posterior and the lateral ligaments, become tense. A similar rotation initiates the movement of flexion, and unlocks the joint by relaxing the ligaments just mentioned.

Since the tibia and foot are fixed in the act of walking, it is the femur which rotates upon the tibia in passing from extension to flexion and *vice versa*; and as relaxation of the ilio-femoral ligament is essential for this rotation, some observers are of opinion that the body weight falls behind the transverse axis of the knee-joint, as in the case of the hip-joint, and consequently that extension of the knee-joint is maintained by the ilio-femoral ligament, as it is not possible to bend the knee without first having bent the hip-joint.

During flexion and extension the semilunar cartilages glide along with the condyles, so as to maintain their close adaptation and preserve their value as packing agents. When the movement of flexion is completed, the condyles are retained upon the tibia, and prevented from slipping off by the tension of the posterior crucial ligament. In this position a small degree of rotation of the tibia, both inwards and outwards, is also permissible.

The regulating and controlling influence of the femoro-patellar portion of the articulation is brought into play during the movements of flexion and extension. In the latter position the inferior pair of patellar facets is in apposition with the upper part of the femoral trochlea. As flexion advances, the middle pair of facets adapt themselves to a deeper area of the trochlea, into which the patellar keel fits. When flexion is still further advanced, the upper pair of patellar facets will be found fitting into that part of the trochlea adjoining the intercondyloid notch;

and finally, when flexion is complete, the patella lies opposite the intercondyloid notch, while the forward thrust of the longer internal condyle brings its semilunar facet (Goodsir) into apposition with the somewhat vertical facet at the inner border of the patella. The wedge-like influence of the patella is most marked, for it is only in the position of extension that it can be moved from side to side. The movements of the patella may be described as gliding and co-aptation, as it slips or rocks from one pair of facets to another in its progress along the trough of the femoral trochlea.

THE TIBIO-FIBULAR JOINTS.

The upper and lower ends of the fibula articulate with the tibia. Primarily, the fibula is required to form a strong lateral support for the ankle-joint, and therefore its articulations are so arranged as to provide a certain amount of elasticity without any sacrifice of the rigidity necessary for security. Hence the amount of movement is very small, but what there is enables these joints to be classified as arthrodial diarthroses.

The **superior tibio-fibular joint** (articulatio tibio-fibularis) is formed, on the one hand, by a flat oval or circular facet which is situated upon the postero-external aspect of the outer tuberosity of the head of the tibia, and is directed downwards and backwards; on the other, by a similar facet on the upper surface of the head of the fibula in front of the styloid process.

A fibrous **capsule** (capsula articularis, Fig. 234) invests the joint, and it may be regarded as holding the articular surfaces in apposition, although certain special bands receive separate designations. Occasionally there is an opening in the capsule by which communication is established between the joint cavity and the knee-joint through the intermediation of the synovial prolongation, subjacent to the tendon of the popliteus muscle.

The **anterior superior tibio-fibular ligament** (lig. capituli fibulæ anterius, Fig. 233) is a strong flat band whose fibres extend from the anterior aspect of the fibular head, upwards and inwards, to the adjoining part of the tuberosity of the tibia.

The **posterior superior tibio-fibular ligament** (lig. capituli fibulæ anterius, Fig. 234) is a similar, but weaker band, passing upwards and inwards from the posterior aspect of the fibular head to the posterior aspect of the outer tuberosity of the tibia, where they are attached immediately below the opening in the capsule of the knee-joint, from which the tendon of the popliteus muscle escapes.

Equally strong but much shorter bands are found on the superior and inferior aspects of the joint. The former is intimately associated with the tendon of the biceps flexor cruris muscle which strengthens the upper aspect of the joint, and here also is found the occasional opening by which it communicates with the knee-joint.

The **synovial membrane** is in certain cases continuous with that of the knee-joint in the manner already described.

The **interosseous membrane** (membrana interossea cruris, Figs. 234 and 237) plays the part of an accessory ligament both for the upper and the lower tibio-fibular joint. It is attached to the interosseous borders on the shafts of the tibia and fibula, and binds them together. The general direction of its fibres is from the tibia downwards and outwards to the fibula, but many fibres pass in the opposite direction. The membrane may extend upwards until it comes into contact with the ligaments of the superior tibio-fibular joint, but there is always a vertical oval aperture in its upper part for the forward passage of the anterior tibial vessels. This aperture (Fig. 234), which is about one inch long, adjoins the shaft of the fibula at a point rather less than one inch below its head. Towards the lower end of the leg the distance between the tibia and the fibula rapidly diminishes, and consequently the width of the interosseous membrane is correspondingly reduced, so that it is tense throughout its entire length. In the lower part of the membrane there is a small opening for the passage of the anterior perforating vessels. There is no sharply-marked demarcation between the interosseous membrane and the interosseous ligament which connects the lower ends of the tibia and fibula—the one, indeed, may be said to run into the other.

The **inferior tibio-fibular joint** (syndesmosis tibio-fibulare) is not on all occasions provided with articular cartilage, so that it may either be a separate articu-

lation, or it may merely present a series of ligaments which are accessory to the ankle-joint, because it is clear that, under any circumstances, the object aimed at in this articulation is to obtain additional security for the ankle-joint. The articular surface on the tibia, when present, constitutes a narrow articular strip on the outer side of the lower end of the bone, and the joint-cavity is practically an upward extension of the ankle-joint. The corresponding fibular facet is continuous with the extensive articular area, by means of which the fibula articulates with the astragalus. By far the greater part of the opposing surfaces of tibia and fibula are, however, non-articular and rough.

The supporting **ligaments** are of great strength.

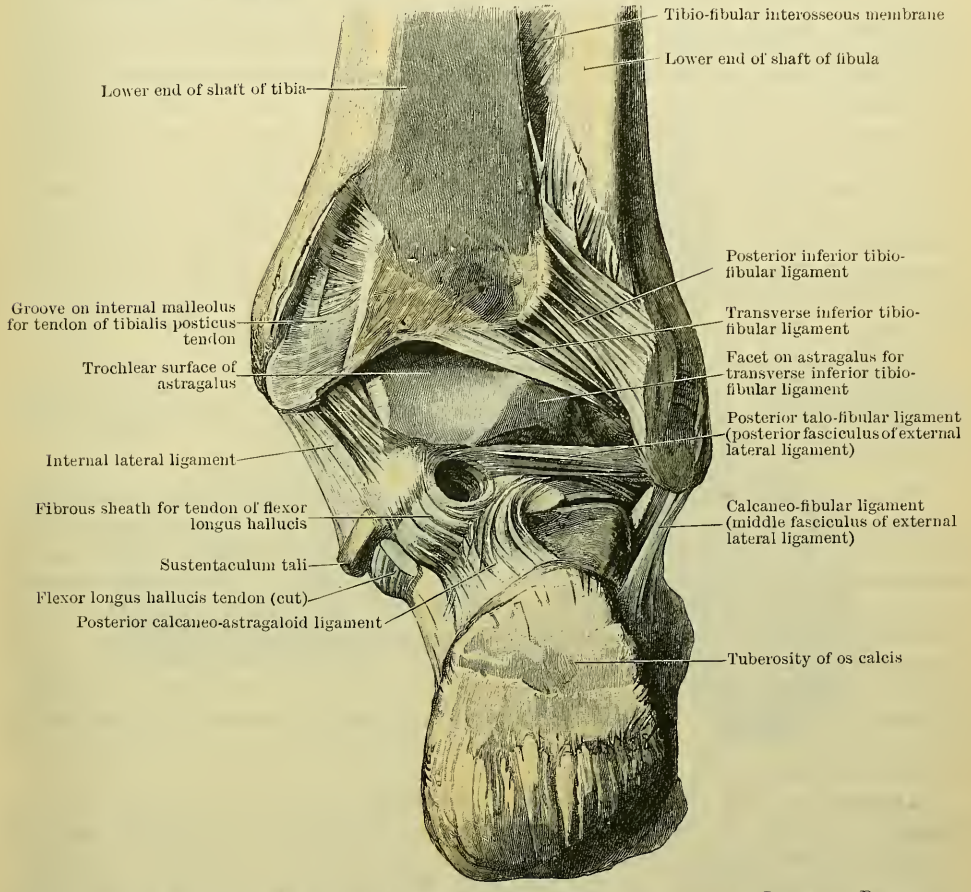


Fig. 237.—Ankle-Joint Dissected from Behind with Part of the Capsular Ligament Removed.

The **anterior inferior tibio-fibular ligament** (lig. malleoli lateralis anterius, Fig. 240) consists of strong fibres which pass obliquely downwards and outwards from the front of the lower end of the tibia to the front of the external malleolus.

The **posterior inferior tibio-fibular ligament** (lig. malleoli lateralis posterius, Figs. 237 and 238) is equally strong, and passes in a similar direction between corresponding posterior surfaces.

A **transverse inferior tibio-fibular ligament** (Figs. 237 and 238) stretches, in the direction indicated by its name, between the posterior inferior border of the tibia and the upper end of the pit on the inner and posterior aspect of the external malleolus.

An **interosseous ligament**, powerful and somewhat extensive, connects the contiguous rough non-articular surfaces. Superiorly, as already mentioned, it is continuous with the interosseous membrane. Anteriorly and posteriorly it comes into contact with the more superficial ligaments. Inferiorly it descends until it comes into intimate association with the joint-cavity.

A **synovial membrane** is found lining the small joint-cavity, but it is always a direct prolongation from that which lines the ankle-joint.

JOINTS OF THE FOOT.

THE ANKLE-JOINT.

The ankle-joint (articulatio talo-cruralis) is a ginglymus variety of a diarthrosis. The bones which enter into its formation are the lower ends of the tibia and fibula, with the articular areas on the upper, lateral, and mesial surfaces of the astragalus. The tibia and fibula, aided by the transverse inferior tibio-fibular ligament, form a three-sided socket within which the astragalus is accommodated. The roof or highest part of the socket, which is wider in front than behind, is formed chiefly by the quadrilateral articular surface which characterises the lower end of the tibia, but towards its postero-external margin the transverse inferior tibio-fibular ligament assists in its formation. Here also the tibial articular surface is continuous with the narrow articular facet already described as forming part of the inferior tibio-fibular joint. The inner wall of the socket is formed by the articular facet on the outer side of the internal malleolus, and there is no interruption of the articular cartilage between the roof and inner wall. The outer wall of the socket is quite separate from the foregoing parts, and consists of a large triangular facet upon the inner side of the external malleolus. This facet is situated immediately in front of the deep pit which characterises the posterior part of this surface of the fibula.

A small lunated facet is frequently found upon the anterior surface of the lower end of the tibia, particularly among those races characterised by the adoption of the "squatting" posture. When this facet exists it is continuous with the anterior margin of the roof of the socket, and it articulates with a similar facet upon the upper surface of the neck of the astragalus in the extreme flexion of the ankle-joint which "squatting" entails.

The articular surface upon the body of the astragalus adapts itself to the tibio-fibular socket, and presents articular facets corresponding to the roof and sides of the socket. Thus the superior surface of the astragalus possesses a quadrilateral articular area, wider in front than behind, distinctly convex in the antero-posterior direction, and slightly concave transversely. In addition, towards its postero-external margin, there is also a narrow antero-posterior facet corresponding to the transverse inferior tibio-fibular ligament. The articular cartilage of this upper surface is continued without interruption to the tibial and fibular sides of the bone, although the margins of the superior area are sharply defined from the lateral facets, the outer of which is triangular in outline, while the inner is pyriform, but in each case the surface is vertical.

Ligaments.—The ligaments form a complete investment for the joint, *i.e.* a **capsule** in which the individual parts vary considerably in strength, and are described under separate names.

The **anterior ligament** is an extremely thin membrane, containing very few longitudinal fibres. It extends from the lower border of the tibia to the upper border of the head of the astragalus, passing in front of a pad of fat which fills up the hollow above the neck of that bone.

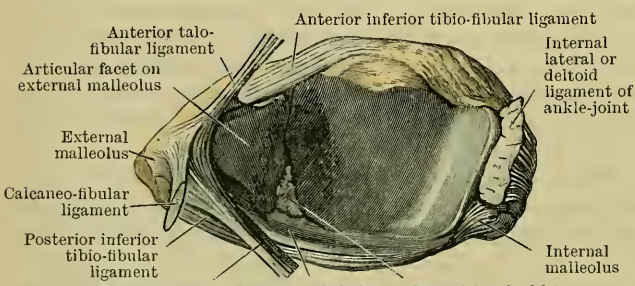


FIG. 238.—ARTICULAR SURFACES OF TIBIA AND FIBULA WHICH ARE OPPOSED TO THE ASTRAGALUS.

The **posterior ligament** is attached to contiguous non-articular borders of the tibia and astragalus. Many of its fibres radiate inwards from the external malleolus. This aspect of the joint is strengthened by the strong, well-defined, transverse ligament already described in connexion with the inferior tibio-fibular joint.

The **external lateral ligament** (Figs. 237, 238, and 240) is very powerful, and is divisible into three fasciculi, which are distinguished from each other by names descriptive of their chief points of attachment.

The *anterior fasciculus* (lig. talo-fibulare anterius) is the shortest. It extends from the anterior border of the external malleolus to the astragalus immediately in front of its external articular surface.

The *middle fasciculus* (lig. calcaneo-fibulare) is a strong and rounded cord. It is attached by one end to the front of the tip of the external malleolus, and by the other to the outer side of the os calcis, immediately above the groove for the peroneal tendons.

The *posterior fasciculus* (lig. talo-fibulare posterius) is the strongest. It runs transversely between the lower part of the fibular or digital fossa on the inner aspect of the malleolus and the posterior surface of the astragalus, where it is attached

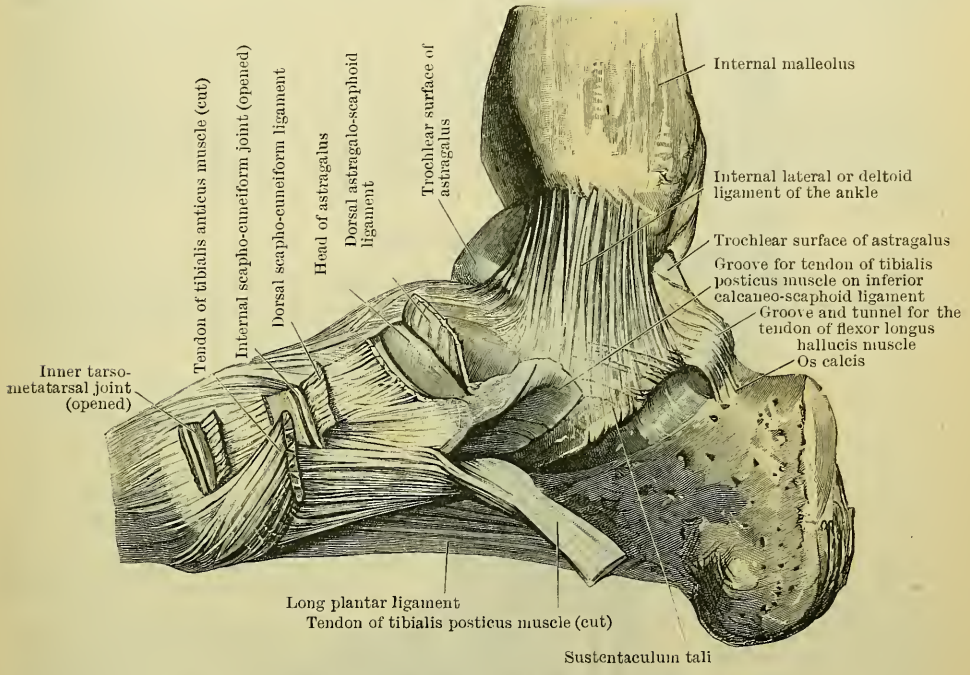


Fig. 239.—Ankle and Tarsal-Joints from the Tibial Aspect.

to the external tubercle and the adjoining rough surface. Sometimes this tubercle is detached from the astragalus, and represents a separate bone—the *os trigonum*.

The **internal lateral ligament** (lig. deltoideum, Figs. 238 and 239) has the general shape of a delta, and is even stronger than the external ligament. It is attached above to a marked impression on the lower part of the internal malleolus, and below, in a continuous layer, to the scaphoid, astragalus, and os calcis. In it we may recognise the following special bands—(*a*) the *lig. talo-tibiale anterius*, which extends from the front of the inner malleolus to the neck of the astragalus; (*b*) the *lig. talo-tibiale posterius*, stretching between the back of the inner malleolus and the postero-internal rough surface of the astragalus; (*c*) the *lig. tibio-naviculare*, which extends from the tip of the inner malleolus to the inner side of the scaphoid; (*d*) the *lig. calcaneo-tibiale*, which extends between the tip of the inner malleolus and the inner side of the sustentaculum tali; (*e*) *lig. talo-tibiale profundum*, which consists of deeper fibres extending from the tip of the internal malleolus to the inner side of the astragalus.

Synovial membrane lines the capsular ligament, and, as already described, the joint-cavity communicates directly with the inferior tibio-fibular joint. Both at the front and back of the ankle-joint, as well as superiorly in the angle formed by the three bones, the synovial membrane covers pads of fat.

Movements at the Ankle-Joint.—In the erect attitude the foot is placed at right angles to the leg; in other words, the normal position of the ankle-joint is **flexion**. Those movements which tend to diminish the angle so formed by the dorsum of the foot and the front of the leg are called **dorsiflexion**, while those which tend to increase the angle, *i.e.* to straighten the foot upon the leg, are called **extension**. As a matter of fact neither dorsiflexion nor extension is ever completely carried out, and the range of movement of which the foot is capable is limited to about 90°. These movements occur about an obliquely transverse axis, as is indicated by the natural outward pointing of the toes. The weight of the body falls slightly anterior to the ankle-joint, so that a certain amount of muscular action is necessitated in order to maintain the foot at right angles to the leg; but additional stability is obtained from the obliquity above mentioned.

When the foot is raised from the ground, muscular action tends naturally to produce a certain amount of extension. When the foot is extended, as in standing on the toes, the hinder narrow part of the astragalus moves forwards into the wider part of the interval between the tibia and fibula, whereas in dorsiflexion, as in raising the fore part of the foot from the ground, the widest part of the astragalus is forced back between the tibia and fibula; but notwithstanding the difference between these two movements, the fibula remains in close contact with the astragalus by reason of the action of the transverse inferior tibio-fibular ligament and the posterior talo-fibular ligament, so that lateral movement is prevented.

It is doubtful whether lateral movement at the ankle-joint can be obtained by any natural movement of the foot, although it is generally believed that in the position of partial extension a small amount of lateral movement may be produced by the application of external force. "This apparent play" of the ankle-joint during extension "is really due to oscillation of the small bones of the foot on each other, largely of the scaphoid on the astragalus, but also of the cuboid on the calcaneum. Excessive mobility of these latter is restrained by an important function of the posterior tubercle of the cuboid which locks into a notch in the os calcis" (Blake).

INTERTARSAL JOINTS.

These joints (articulationes intertarseæ) are all diarthroses in which the gliding movement is characteristic, as in the carpus. With the view of obtaining a proper con-

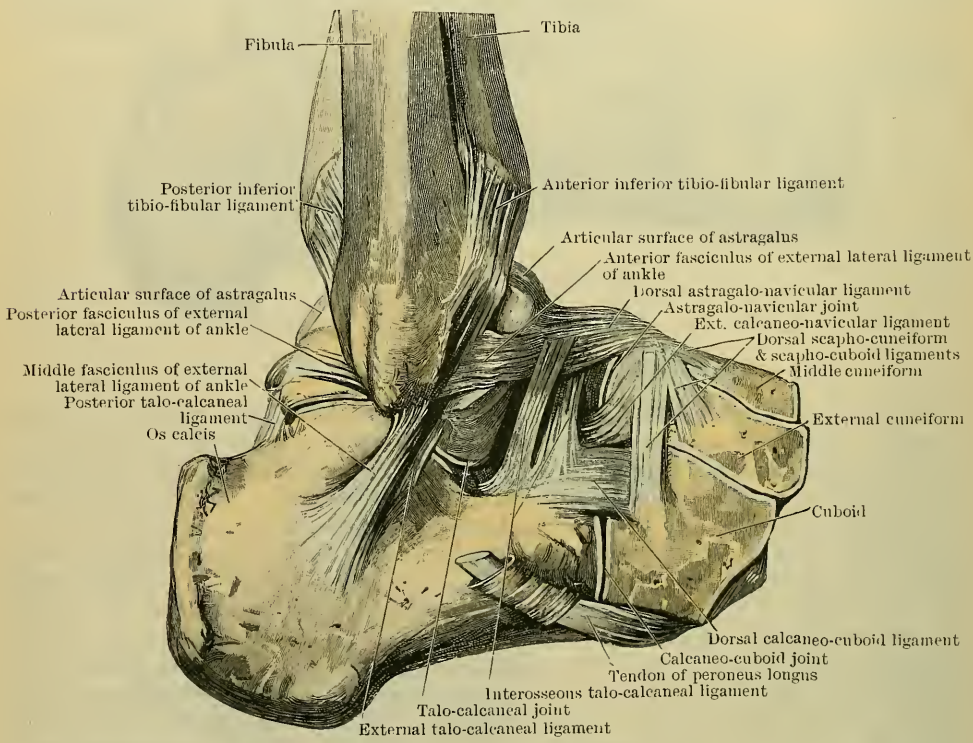


FIG. 240.—LIGAMENTS ON THE OUTER ASPECT OF THE ANKLE-JOINT AND ON THE DORSUM OF THE TARSUS.

ception of the many beautiful mechanical principles involved in the construction of the foot, it is necessary to study these articulations with considerable attention to detail.

Articulatio Talo-calcanea.—The astragalus and os calcis articulate with each other in the articulatio talo-calcanea or calcaneo-astragaloid joint.

This joint is situated between the inferior facet on the body of the astragalus

and a corresponding facet on the upper aspect of the hinder part of the os calcis. On each bone the articulation is limited in front by a wide, deep groove which runs obliquely across each bone from within outwards and forwards.

The supporting and investing ligaments form a **capsule**, consisting for the most part of short fibres, but the joint derives additional strength from the external and internal lateral ligaments of the ankle-joint. The capsule is subdivided into the following astragalo-calcaneal or talo-calcaneal bands:—

The **anterior talo-calcaneal ligament** consists of a band of short fibres placed immediately in relation to the anterior end of the deep groove which bounds the articular facets. They are attached to the antero-external aspect of the neck of the astragalus, from which they extend downwards to the adjacent superior surface of the os calcis.

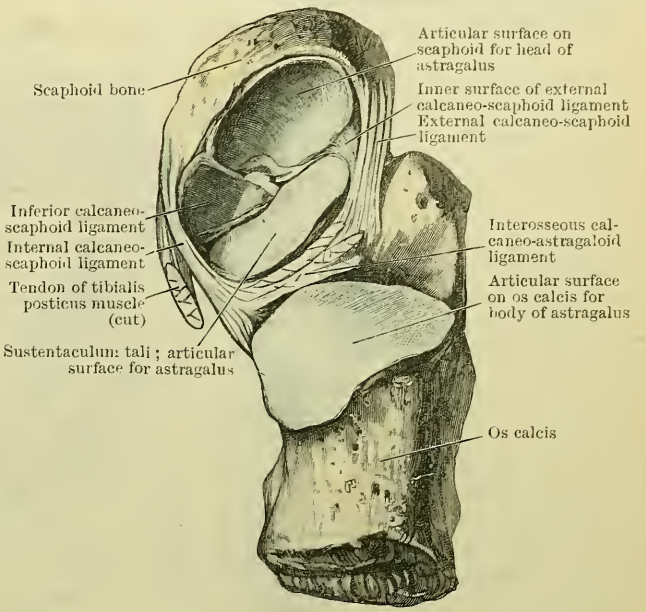


Fig. 241.—The Composite Articular Socket for the Head of the Astragalus.

The **external talo-calcaneal ligament** (Fig. 240) is in continuity with the hinder border of the preceding ligament, and it is placed parallel to, but on a deeper plane than, the middle fasciculus of the external lateral ligament of the ankle-joint. It consists of short fibres passing between the adjacent rough outer margins of the two bones.

The **posterior talo-calcaneal ligament** (Fig. 240) closes the joint-cavity on its posterior aspect. It consists of fibres which radiate from the posterior aspect of the external tubercle of the astragalus to the upper surface of the os calcis, immediately behind the articular facet.

The **internal talo-calcaneal ligament** lies obliquely on the inner side of the joint, and consists of fibres which extend from the inner posterior tubercle of the astragalus to the hinder roughened border of the sustentaculum tali. Some of its fibres become continuous with the internal calcaneo-scaphoid ligament.

The **interosseous talo-calcaneal ligament** (Fig. 240) closes the antero-internal aspect of the joint. It is the strongest of the series of ligaments entering into the capsule. Compared with it the other bands are, comparatively speaking, insignificant. Its attachments are to the bottom of each groove, so that it occupies the tarsal canal formed by these opposing grooves.

A **synovial membrane** lines the capsule, and it is distinct from other tarsal synovial membranes.

Articulatio Talo-calcaneo-navicularis.—This is one of the most important of the joints of the foot, not only because the astragalus is here situated in relation to the summit of the antero-posterior arch of the foot, but because the head of the astragalus is received into a composite socket made up of sustentaculum tali, scaphoid, and the inferior or internal calcaneo-scaphoid ligament.

The articular surface on the head of the astragalus presents anteriorly a convex rounded facet for articulation with the scaphoid, inferiorly a convex facet which rests upon the sustentaculum tali, and intermediate between these two there is a triangular facet which articulates with the inferior calcaneo-scaphoid ligament. All these facets are in continuity with each other, and are in front of the tarsal groove on the under surface of the astragalus. Occasionally a fourth narrow facet is

found along the outer and hinder part of the articular surface of the head of the astragalus, whereby it articulates with superior or external calcaneo-scaphoid ligament.

The scaphoid or navicular bone presents a shallow, cup-shaped, articular cavity towards the head of the astragalus.

The articular surface of the sustentaculum tali is concave, and is usually marked off into two facets.

Two ligaments play an important part in binding together the os calcis and the scaphoid, although these bones do not directly articulate; and further, these ligaments provide additional articular surfaces for the head of the astragalus. These are the two following:—

(*a*) The **inferior** or **internal calcaneo-scaphoid ligament** (Figs. 239 and 242) is an

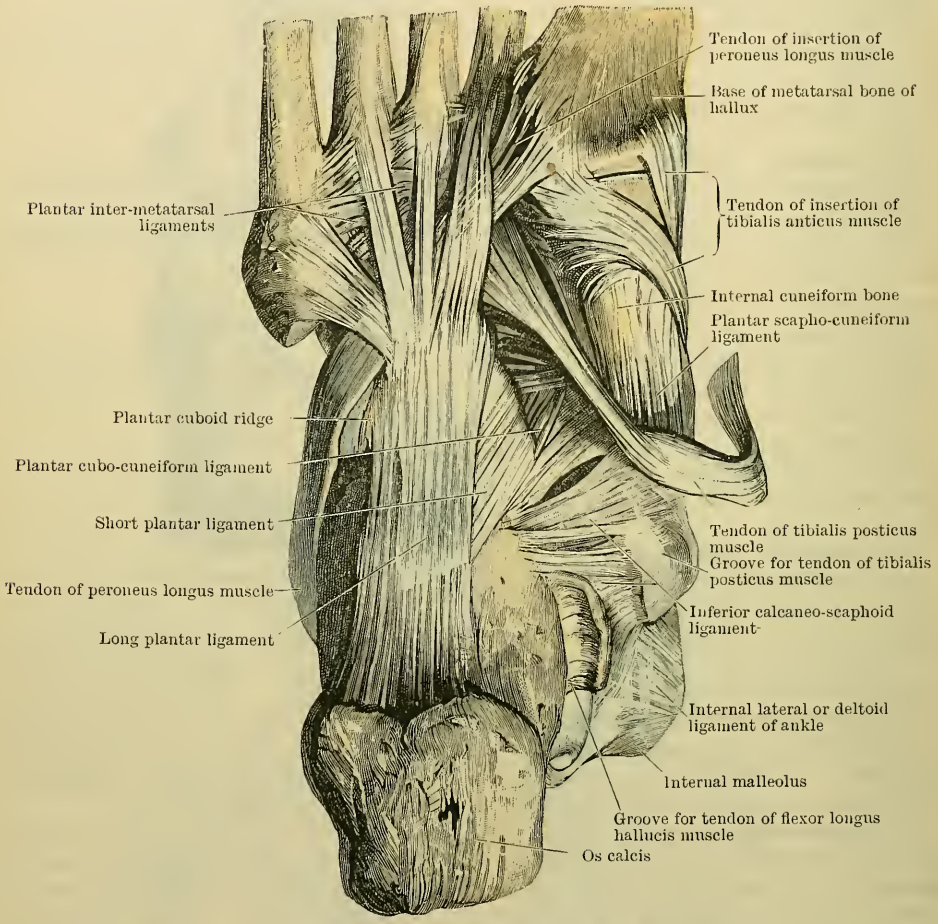


FIG. 242.—PLANTAR ASPECT OF TARSAL AND TARSO-METATARSAL JOINTS.

extremely powerful fibro-cartilaginous tie-band. It extends between the anterior margin of the sustentaculum tali and the inferior surface of the scaphoid bone. Certain of its upper fibres radiate upwards on the inner surface of the scaphoid, and become continuous with the tibio-navicular portion of the deltoid ligament of the ankle-joint. The plantar aspect of this ligament is in contact with the tendon of the tibialis posticus muscle, through which the head of the talus receives great support. Superiorly it contributes an articular surface which forms a triangular portion of the floor of the composite socket in which the head of the talus is received.

(*b*) The **superior** or **external calcaneo-scaphoid ligament** (Fig. 241) lies deeply in the front part of the sinus tarsi, *i.e.* the interval between the astragalus and os calcis. Its fibres are short, and extend from the dorsal surface of the front part of the os calcis, immediately to the outer side of the sustentacular facet, forwards to the outer side of the scaphoid bone. Frequently the ligament presents a surface

which articulates with the head of the astragalus, and in these cases it forms a part of the composite socket.

The cavity of the talo-calcaneo-navicular joint is closed posteriorly by the interosseous talo-calcaneal ligament already described. On its inner and outer inferior aspects it is closed by the calcaneo-scaphoid ligaments.

The superior and lateral aspects are covered by an **astragalo-scaphoid membrane** or **ligament.** This ligament is thin, and extends from the upper non-articular area on the head of the astragalus to the dorsal surface of the scaphoid bone. It may be subdivided into *dorsal* (superior), *lateral* (external), and *medial* (internal), **astragalo-scaphoid ligaments** (Fig. 239), which, with the calcaneo-scaphoid and interosseous talo-calcaneal ligaments, complete the capsular investment of the joint.

A distinct **synovial membrane** lines all parts of the capsule of the joint.

Articulatio Calcaneo-cuboidea.—This is situated between the anterior concavo-convex surface of the os calcis and the posterior similar surface of the cuboid.

The **ligaments** which invest this joint constitute a **calcaneo-cuboid capsule,** whose parts are arranged in relation to the four non-articular sides of the cuboid bone, and are especially strong upon the plantar aspect, in relation to their great importance in resisting strains.

The **internal calcaneo-cuboid ligament** occupies part of the interval between the astragalus and os calcis—sinus tarsi. It is sometimes called the interosseous calcaneo-cuboid ligament, and, in conjunction with the superior or external calcaneo-scaphoid ligament, it forms a V-shaped structure, of which the single end is attached to the os calcis, and the double ends separate to reach contiguous areas on the scaphoid and cuboid respectively.

The **dorsal calcaneo-cuboid ligament** (Fig. 240) is a broad portion of the capsule extending between the dorsal surfaces of the two bones.

The **external calcaneo-cuboid ligament** is another but narrower part of the capsule which extends from the outer aspect of the os calcis to the outer side of the cuboid, immediately behind the facet on the tuberosity.

The **inferior calcaneo-cuboid ligaments** are two in number—a superficial and a deep. The superficial series of fibres, the **long plantar ligament** (Fig. 242), is attached to the under surface of the os calcis in front of its tuberosities. It forms a long powerful structure which runs forwards to be fixed to the under surface of the cuboid ridge, but many of its fibres pass superficial to the tendon of the peroneus longus, and extend to the bases of the third, fourth, and fifth metatarsal bones.

The deep series of fibres, the **short plantar ligament** (Fig. 242), is distinctly separated from the former by a layer of areolar tissue. It forms a broad but short band of great strength, which is attached to the under surface of the front end of the os calcis, and extends to the under surface of the cuboid just behind the ridge. Both of these ligaments are of great importance in maintaining the longitudinal arch of the foot, and in this respect are only second to the inferior calcaneo-scaphoid ligaments.

A **synovial membrane** lines the capsule.

Transverse Tarsal Articulation.—This is a term sometimes applied to the astragalo-scaphoid and calcaneo-cuboid joints. These articulations do not communicate with each other; and although there is an occasional direct articulation between the scaphoid and cuboid, it does not constitute an extension of the transverse tarsal joint, but is a prolongation from the series of scapho-cuneiform and cuneo-cuboid articulations.

Nevertheless there is always a set of **ligaments** which bind the scaphoid and cuboid bones together, and these may be regarded as accessory to the various transverse tarsal joints.

The **dorsal scapho-cuboid ligament** (Fig. 240) consists of short oblique fibres which attach the contiguous dorsal surfaces of the cuboid and scaphoid bones.

The **plantar scapho-cuboid ligament** is transverse in direction, and extends between adjacent plantar areas of the cuboid and scaphoid bones.

The **interosseous scapho-cuboid ligament** intervenes between contiguous surfaces of the same bones. When there is an extension of the scapho-cuneiform joint backwards between the scaphoid and cuboid, it is situated in front of the last-mentioned ligament, and is called the **articulatio scapho-cuboidea.** Around this joint

the preceding ligaments are grouped. Since, however, the joint is inconstant while the ligaments are always present, it is preferable to consider them as above indicated.

Scapho-cuneiform Articulation (articulatio cuneo-navicularis).—This joint is situated between the scaphoid and the three cuneiform bones. The anterior surface of the scaphoid presents facets for each of the cuneiform bones, but its articular surface is not interrupted. These facets form a somewhat convex anterior surface which fits into the shallow articular concavity presented by the proximal ends of the three cuneiform bones. This joint may be extended by the occasional scapho-cuboid articulation already referred to.

The **capsule** is composed of short, strong bands which are distinctly visible on all sides except towards the cuboid bone, where the joint may communicate with the cuneo-cuboid and scapho-cuboid joints. Anteriorly the joint communicates with the intercuneiform articulations. The dorsal parts of the capsule are short longitudinal bands termed **dorsal scapho-cuneiform ligaments** (Figs. 239 and 240). These extend without interruption to the inner aspect of the joint. Inferiorly there are similar bands, known as **plantar scapho-cuneiform ligaments**, also longitudinal in direction, but intimately associated with offsets from the tendon of the tibialis posticus muscle.

The **synovial membrane** which lines the capsule sends prolongations forwards on each side of the middle cuneiform bone, and in addition it often communicates with the cuneo-cuboid joint cavity, and it always communicates with the scapho-cuboid cavity when that joint exists.

Intercuneiform Articulations.—These are two in number, and exist between adjacent contiguous surfaces of the three cuneiform bones. These surfaces are partly articular and partly non-articular. The small size of the middle cuneiform bone allows the internal cuneiform as well as the external cuneiform to project forwards beyond it on both sides, and therefore the articular surfaces turned towards the middle cuneiform are not entirely occupied by that bone. They form a recess towards the metatarsus, into which the base of the second metatarsal bone is thrust.

Dorsal intercuneiform ligaments constitute fairly strong transverse bands which extend between adjacent dorsal surfaces and invest the joint cavities in this direction.

The plantar or **interosseous intercuneiform ligaments** are two strong bands which pass from the rough non-articular areas on opposite sides of the middle cuneiform to the opposing surfaces of the inner and outer cuneiform bones. These ligaments shut in the joint cavities inferiorly, and also anteriorly in the case of the outer of the two joints.

The **synovial membrane** is an extension of that which lines the scapho-cuneiform joint; but while it is restricted to the outer of the two joints, in the case of the inner one it is prolonged still farther forward to the tarso-metatarsal series of joints.

Cubo-cuneiform Articulation.—This occurs between the rounded or oval facets on the opposing surfaces of the cuboid and external cuneiform.

The **dorsal cubo-cuneiform ligament** is a flat, somewhat transverse band which closes the joint on its superior aspect, and extends between the dorsal surfaces of the two bones.

The **plantar cubo-cuneiform ligament** is difficult to determine. It is situated subjacent to the long plantar ligament, and extends between adjacent rough surfaces of the two bones.

The **interosseous cubo-cuneiform ligament** is the strongest. It closes the joint cavity anteriorly, and is attached to the contiguous non-articular surfaces of the two bones.

The **synovial membrane** is frequently distinct, but at other times the joint cavity communicates with those of the scapho-cuneiform and scapho-cuboid articulations.

Synovial Membranes of the Intertarsal Joints.—Four and sometimes five distinct and separate synovial membranes may thus be enumerated in connexion with the tarsal articulations, viz.: (1) talo-calcaneal; (2) talo-calcaneo-navicularis; (3) calcaneo-cuboid; (4) scapho-cuneiform and its extensions; (5) occasionally cubo-cuneiform.

TARSO-METATARSAL JOINTS.

The tarso-metatarsal joints are found between certain articular facets on the cuboid and three cuneiform bones on the one hand, and others on the bases of the five metatarsal bones. These articulations are associated with three distinct synovial cavities—namely, an inner, middle, and outer.

(1) The **inner tarso-metatarsal articulation** occurs between the distal convex reniform surface of the internal cuneiform bone and the concavo-reniform surface on the proximal aspect of the base of the first metatarsal bone.

Ligaments which form a **capsule** surround the articulation. In the capsule the **dorsal** and **plantar tarso-metatarsal bands** are its strongest parts, but it is not deficient either on the inner or on the outer aspects.

A separate **synovial membrane** lines the capsule.

(2) The **middle tarso-metatarsal articulation** is an elaborate joint. It involves the three cuneiform bones and the bases of the second, third, and part of the fourth metatarsal bones.

The articulation presents the outline of an indented parapet both on its tarsal and its metatarsal aspects. Thus, on its tarsal side, the inner and the outer cuneiform bones project in front of the middle cuneiform, so that the latter only presents a distal surface to the articulation; while the internal cuneiform presents a portion of its external surface, and the external cuneiform presents both its distal and portions of its outer and inner surfaces, since it projects in front of the cuboid bone. On its metatarsal side the base of the second metatarsal bone fits into the indentation between the outer and inner cuneiforms, to which it presents external and internal articular facets, but its proximal facet rests upon the distal facet of the middle cuneiform. The base of the third metatarsal bone rests its proximal facet upon the outer cuneiform. The fourth metatarsal base presents part of its internal facet to the external side of the outer cuneiform. In this way the indentations alternate on the two sides of the articulation, and an extremely powerful interlocking of parts is provided, which places any marked independent movement of these metatarsal bones entirely out of the question.

The **dorsal tarso-metatarsal ligaments** are broad, flat bands which represent the most distinct part of an investing **capsule**. They pass from behind forwards, and while the second metatarsal bone receives three, *i.e.* one from each cuneiform, the third metatarsal only receives one—from the external cuneiform.

The **plantar tarso-metatarsal ligaments** correspond with the foregoing in their general arrangement, but they are weaker. That for the second metatarsal is the strongest. Oblique bands extend from the inner cuneiform bone to the second and third metatarsals.

The **interosseous cuneo-metatarsal ligaments** are three in number. The *inner* connects the outer side of the internal cuneiform with the inner side of the base of the second metatarsal bone. The *middle* connects the inner side of the external cuneiform with the outer side of the base of the second metatarsal. The *outer* connects the adjacent outer sides of the external cuneiform and third metatarsal.

The **synovial membrane**, which lines this articulation, sends a prolongation backwards between the inner and middle cuneiform bones, where it opens into the scapho-cuneiform joint. It is likewise prolonged forwards upon both sides of each of the bases of the second and third metatarsal bones.

(3) The **external tarso-metatarsal articulation** is found between the proximal surfaces of the bases of the fourth and fifth metatarsal bones and the distal surface of the cuboid.

The investing **capsule** may be resolved into the following ligaments:—

The **dorsal tarso-metatarsal ligaments** resemble those already described. The base of the fourth metatarsal receives one from the external cuneiform and one from the cuboid. The base of the fifth metatarsal receives one from the cuboid.

The **plantar tarso-metatarsal ligaments** are the weakest bands of the series, and consist of scattered fibres passing from the cuboid to the bases of the two metatarsals. Some fibres, which are almost transverse, extend from the

external cuneiform to the fifth metatarsal, and additional fibres reach the metatarsals in question from the long plantar ligament (calcaneo-cuboid).

Occasionally the tarsal end of the external interosseous (cuneo-metatarsal) ligament is attached to the inner margin of the cuboid.

The **synovial membrane** is restricted to this articulation, and merely sends a prolongation forwards between the opposing articulate aspects of the fourth and fifth metatarsal bases.

INTERMETATARSAL JOINTS.

The intermetatarsal articulations are found between adjacent lateral aspects of the bases of the four outer metatarsal bones. The articular facets are small, oval, or rounded surfaces which occupy only a limited portion of the flattened contiguous surfaces of the bones. Each joint is provided with a **capsule**, which, however, is not a complete investment, because the three joint cavities are in free communication on their proximal aspects with the tarso-metatarsal joint cavities—one with the outer and two with the middle. The definite fibres of each capsule are situated chiefly in the transverse direction.

The **dorsal ligaments** are short bands which extend from one base to the other.

The **plantar** and **interosseous ligaments** are similarly arranged, but the latter are the strongest and most important members of this series.

The **synovial membranes** are extensions from those which line the outer and middle tarso-metatarsal joint cavities.

Frequently a bursa is found between the bases of the first and second metatarsal bones. It produces an appearance of indistinct facetting upon these bones, and it may communicate with the inner tarso-metatarsal (cuneo-metatarsal) joint.

The **transverse metatarsal ligament** lies upon, and is attached to, the non-articular plantar aspects of the heads of all the metatarsal bones. It differs from the corresponding ligament in the palm in the fact that it binds all the metatarsal bones together, whereas in the palm the thumb is left free. It is closely associated with the plantar fibrous plates of the metatarso-phalangeal joints, to the plantar surfaces of which it contributes prolongations termed ligamenta accessoria plantaria.

METATARSO-PHALANGEAL JOINTS.

Each of these joints is a modified ball-and-socket in which a shallow cup upon the bases of the first phalanges receives the somewhat globular head of a metatarsal bone.

Each joint retains a modified **capsule** which invests the joint. Its only distinct bands are the **ligamenta collateralia**. These are strong cord-like bands which are situated on the inner and outer sides of each joint, where they extend between adjacent rough surfaces.

On the dorsal aspect ligaments distinct from the dorsal expansion of the extensor tendons can hardly be said to exist. The plantar aspect of the capsule consists of a thick **fibrous plate**, which in the case of the great toe presents developed within it two large sesamoid bones. In the other toes this plate remains fibrous throughout, and is grooved on its plantar aspect for the accommodation of the long flexor tendons. It will thus be seen that the metatarso-phalangeal joints are constructed upon a plan very similar to that of the corresponding joints in the hand.

A **synovial membrane** lines the capsule of each articulation.

INTERPHALANGEAL JOINTS.

Each toe possesses two interphalangeal joints except the great toe, which has only one. Not unfrequently in the little toe the distal joint is obliterated through ankylosis. All the joints of this series are uniaxial or hinge joints. The nature of the articular surfaces closely resembles the corresponding joints in the fingers.

Each joint possesses a **capsule** which is either very thin or limited to synovial membrane on the dorsal aspect. The plantar surface of the capsule is strength-

ened by a **fibrous plate**. The **lateral ligaments** (ligamenta collateralia) are well-defined bands similar to those already described in connexion with the metatarso-phalangeal joints.

A **synovial membrane** lines each capsule in the series.

Mechanism of the Foot.—The bones of the foot are arranged in the form of a longitudinal and a transverse arch. The longitudinal arch is built on a very remarkable plan. Posteriorly the mass of the os calcis constitutes a rigid and stable pier of support, while anteriorly, by increasing the number of component parts, the anterior pier acquires great flexibility and elasticity without sacrificing strength or stability. The summit of the arch is formed by the astragalus, which receives the weight of the body from the tibia, and the resilience of the arch is assured by the calcaneo-scaphoid and calcaneo-cuboid ligaments, together with the plantar fascia, which act as powerful braces or tie bands, preventing undue separation of the piers of the arch, and consequent flattening of the foot. The weight of the body is distributed over all the five digits, owing to the arrangement of the bones of the foot in two parallel columns, an **inner** and an **outer**. The former, consisting of the astragalus, scaphoid, and the three cuneiforms, with the three inner metatarsal bones, distributes weight through the talo-scaphoid joint, while the latter (*i.e.* the outer column), comprising the calcaneum, cuboid, and the two outer metatarsal bones, acts in a similar manner through the talo-calcanean joint. The main line of immobility of this arch passes from the heel forwards through the middle toe, but its anterior section, which is slender, is supported on either side by two metatarsal bones, with their proximal tarsal associations, in all of which greater freedom of movement is found. The transverse arch is most marked at the level of tarso-metatarsal articulations. The intersection of these two arches at right angles to each other introduces an architectural feature of great importance in connexion with the support of heavy weights. These longitudinal and transverse arches of the foot are in effect "vaults" intersecting each other at right angles, and in relation to the area which is common to both "vaults" the body weight is superposed exactly as the dome of a cathedral is carried upon two intersecting vaults.

Movements at the Joints of Tarsus, Metatarsus, and Phalanges.—Considered in detail, the amount of movement which takes place between any two of these bones is extremely small, and, so far as the tarsus and metatarsus are concerned, it is mostly of the nature of a gliding motion.

At the metatarso-phalangeal and interphalangeal joints movement is much more free, and is of the nature of **flexion** (bending of the toes towards the sole of the foot, *i.e.* plantar flexion) and **extension**. The latter movement when continued so as to raise the toes from the ground, and bend or approximate them towards the front of the leg, is termed **dorsiflexion**. Coincident with dorsiflexion there is always associated a certain amount of spreading of the toes, which is called **abduction**, and similarly with prolonged flexion there follows a diminution or narrowing of the transverse diameter of the front part of the foot by drawing the toes together—a movement termed **adduction**. In the foot the movements of abduction and adduction take place in regard to a plane which bisects the foot antero-posteriorly through the second toe, for this toe carries the first and second dorsal interosseous muscles.

Notwithstanding the small amount of possible movement in connexion with individual tarsal and metatarsal joints, yet the sum total of these movements is considerable as regards the entire foot. In this way the movements of **inversion** and **eversion** of the foot result. By inversion we mean the raising of the inner border of the foot so that the sole looks inwards, while the toes are depressed towards the ground, and the outer border of the foot remains downwards. This takes place chiefly at the talo-calcanean joint, but the transverse tarsal joints also participate.

Eversion is chiefly the opposite of inversion, and the return of the foot to the normal position of the erect attitude; but under certain conditions it may be carried further, so that the outer border of the foot is raised from the ground, while the inner border is depressed. In both of these movements there is **rotation** between the astragalus and os calcis about an oblique axis which passes from the inner side of the neck of the astragalus to the outer and lower part of the os calcis.

Of course all the movements of the foot are subordinated to its primary functions as an organ of support and progression. For these purposes its longitudinal and transverse arches are of extreme importance. The longitudinal arch resting on the os calcis behind and the heads of the metatarsal bones in front receives the weight of the body, as already explained, on the summit of the astragalus in the line of the third toe. Hence it is that the inner malleolus appears to be unduly prominent on the inner side of the ankle. The transverse arch buttresses the longitudinal one, and therefore, whether the body weight fall to the outer or the inner side of the longitudinal arch, it is supported by a mechanism at once stable, flexible, and elastic, or resilient, and capable of reducing to a minimum all jars that may be received by the fore-part of the foot. As the heel is raised in the act of walking, the weight is gradually transferred from the outer to the inner side of the foot, until the foot finally leaves the ground with a propulsive movement, which results from flexion of the phalanges of the great toe. In this connexion it is worthy of note that the longitudinal line of greatest strength is on the inner side of the longitudinal arch, *i.e.* in relation to the great toe.

THE MUSCULAR SYSTEM.

MYOLOGY.

By A. M. Paterson.

The movements of the various parts and organs of the body are brought about by the agency of muscle-cells, which are characterised by a special histological structure and by the special function of contracting in length under the influence of a proper stimulus.

There are three classes of muscle-cells: (1) the striated, and usually voluntary muscle-cells, out of which the skeletal muscular system is constructed; (2) the non-striated, involuntary muscle-cells, occurring in the walls of vessels and hollow viscera, etc.; and (3) the cardial muscle-cells, striated but involuntary, of which the substance of the heart is composed.

The following section deals solely with the skeletal muscles, the structure, arrangement, and mechanical action of which are based upon a common plan.

The cells of which the skeletal muscles are composed are long, narrow, and characterised by a peculiar striation, which is different from the striation of the muscle-cells of the heart; they also differ both in structure and function from the non-striated muscle-cells which occur in viscera and vessels.

A **typical skeletal muscle** consists of a fleshy mass enveloped in a membranous aponeurosis or fascia, and provided at its extremities or borders with membranous or tendinous attachments to bone, cartilage, or fascia.

Each muscle is made up of a number of **fasciculi** or bundles, arranged together in different muscles in different ways, so as to give rise to the particular form of the muscle in question. These fasciculi are connected together by a delicate connective tissue, the **perimysium externum**, continuous externally with the aponeurosis enclosing the muscle.

Each muscular bundle or fasciculus is composed of a number of narrow, elongated **muscle-cells** or fibres, held together by a still more delicate connective tissue, the **perimysium internum**. This tissue is connected on the one hand with the **sarcolemma** or cell-wall of the muscle-cell, and on the other hand with the coarser tissue of the perimysium externum enclosing the muscular bundles.

By means of these connective tissue envelopes the muscle-cells, the essential agents of motor activity, are brought into firm and intimate relation with the osseous or other attachments of the muscle. Through the agency of sarcolemma, perimysium internum, perimysium externum, aponeurosis, and tendon, the muscle-cell when it contracts can produce a precise and definite effect upon the weight to be moved.

Each muscle is supplied by one or more nerves, which, in their course through the muscle, separate into smaller and smaller branches, ultimately, by their terminal filaments (axons), forming special end-organs in relation to each muscle-cell.

While a muscle may thus be looked upon as an organ endowed with particular properties, and executing a definite movement in response to a stimulus by the simultaneous contraction of its constituent cells, the various muscles may further be considered in groups, associated together by mode of development, nerve-supply, and co-ordination of action. For example, we speak of the hamstring muscles of

the thigh, the muscles of the back, and the prævertebral muscles—groups in which separate muscles are associated together by development, nerve-supply, and action. In their development the separate muscles arise from the subdivision of a larger stratum, as in the limbs, or from the fusion of segmental elements (myotomes), as in the case of the axial muscles; the peripheral nerves supplying skeletal muscles are distributed, through the plexuses or directly, so as to associate particular muscles morphologically and physiologically, and to secure a co-ordinated movement by the simultaneous contraction of several muscles together.

FASCIÆ.

Beneath the skin there are two (or in some regions three) layers of tissue which require consideration: the superficial fascia (panniculus adiposus), the deep fascia (fascia lata), and, in animals, the panniculus carnosus (rudimentary in man, and represented chiefly by the *platysma myoides* in the neck).

Superficial Fascia.—The superficial fascia is a continuous sheet of areolar tissue which underlies the skin of the whole body. It is closely adherent to the cutis vera, and is sometimes termed **panniculus adiposus**, from the fact that, except beneath the skin of the eyelids, penis, and scrotum, it is always more or less impregnated with fat. It is traversed by the cutaneous vessels and nerves; and its deep surface, membranous in character, is in loose connexion with the subjacent deep fascia. It is in this layer that dropsical effusions chiefly occur.

Deep Fascia.—Underneath the skin and superficial fascia is a fibrous membrane, bluish white in colour, devoid of fat, and in closest relation to skeleton, ligaments, and muscles. This is the deep fascia. It covers, invests, and in some cases forms the means of attachment of the various muscles. It has a special tendency to become attached to all subcutaneous bony prominences, and to be continuous with the connecting ligaments. It forms septal processes, which separate groups of muscles and individual muscles; enclose glands and viscera; and form sheaths for vessels and nerves. Around joints it gives rise to bands which strengthen the capsule or limit the mobility of the joint, or, as in the case of annular ligaments, bind down the tendons passing over the joint. It not only ensheathes vessels and nerves, but is perforated by those which pass between superficial and deeper parts.

The term **aponeurosis** is used in relation to muscles. It is synonymous with deep fascia, either as an investing fascia, or as a membranous layer which (*e.g.* vertebral aponeurosis) performs at one and the same time the purpose of a deep fascia and the expanded membranous attachment of a muscle.

The **panniculus carnosus** is a thin muscular layer enveloping the trunk of animals with a hairy or furry coat. It is strongly developed in the hedgehog. In man it is represented mainly in the (rudimentary) platysma myoides. It is placed between the superficial and the deep fascia.

Bursæ.—Where a tendon passes over a bony surface, or where the superficial fascia and skin cover a bony prominence, there is generally formed a synovial sac, or bursa, containing fluid, for the purpose of lubricating the surface over which the tendon or fascia glides. Allied to these are the synovial sheaths which envelop tendons beneath the annular ligaments in relation to the several joints.

Description of Muscles.—In studying the muscular system it is necessary to note the following characters in reference to each individual muscle: (1) The *shape* of the muscle—flat, cylindrical, triangular, rhomboidal, etc.—and the character of its extremities—membranous, tendinous, or fleshy. (2) The *attachments* of the muscle. The *origin* is the more fixed or central attachment: the *insertion* is the more movable or peripheral attachment. (3) The *relations* of the surfaces and borders of the muscle to bones, joints, other muscles, and other important structures. (4) Its *vascular* and *nervous supply*; and (5) *its action.* It must be borne in mind that hardly any single muscle acts alone. Each muscle, as a rule, forms one of a group acting more or less in harmony with, and antagonised by, other and opposite groups.

DESCRIPTION OF THE MUSCLES.

The skeletal muscles may be divided into two series: axial and appendicular. The **axial** muscles comprise the muscles of the trunk, head, and face, including the **panniculus carnosus** (platysma myoides). These muscles are more or less segmental in arrangement, grouped around the axial skeleton. The **appendicular muscles**, the muscles of the limbs, are grouped around the appendicular skeleton. They are not segmental in arrangement, they are clearly separate from the axial muscles, and they are arranged in definite strata in relation to the bones of the limbs.

APPENDICULAR MUSCLES.

THE UPPER LIMB.

FASCIÆ AND SUPERFICIAL MUSCLES OF THE BACK.

Fasciæ.

The **superficial fascia** of the back presents no peculiarity. It is usually of considerable thickness, and contains a quantity of fat.

The **deep fascia** closely invests the muscles. It is attached in the middle line of the back to the ligamentum nuchæ, supraspinous ligaments, and vertebral spines; laterally it is attached to the spine of the scapula and the clavicle, and is continued over the deltoid region to the arm. In the neck it is attached above to the superior curved line of the occipital bone, and is continuous laterally with the deep cervical fascia. Below the level of the arm it is continuous round the border of the latissimus dorsi muscle, with the fascia of the axilla and of the abdominal wall. In the back and loin it constitutes the **vertebral aponeurosis** or aponeurosis of the latissimus dorsi. It conceals the erector spinæ muscle, forming the posterior layer of the **lumbar fascia**, and it is attached internally to the vertebral spines, and externally to the angles of the ribs, to the lumbar fascia, and to the iliac crest.

The Superficial Muscles of the Back.

The muscles of the back are arranged in four series according to their attachments: (1) vertebro-scapular and vertebro-humeral; (2) vertebro-costal; (3) vertebro-cranial; and (4) vertebral. The first of this series consists of the posterior muscles connecting the upper limb to the trunk, and comprises the first two layers of the muscles of the back—(1) trapezius and latissimus dorsi, and (2) levator anguli scapulæ and rhomboidei (major and minor). The deeper (axial) muscles of the back are dealt with later.

The **trapezius** (m. trapezius, cucullaris) is a large triangular muscle occupying the upper part of the back. It **arises** from the superior curved line of the occipital bone in its inner third, from the external occipital protuberance (Fig. 312, p. 397), from the ligamentum nuchæ, from the spines of the seventh cervical and all the thoracic vertebræ, and the corresponding supra-spinous ligaments. The origin is by direct fleshy attachment, except in relation to the occipital bone, the lower part of the neck, and the lower thoracic vertebræ, in which places the origins are tendinous. From their origin the muscular fibres converge towards the bones of the shoulder, to be **inserted** continuously from before backwards as follows: (1) The occipital and upper cervical fibres—into the posterior surface of the clavicle in its outer third (Figs. 243, p. 319, and 248, p. 324); (2) the lower cervical and upper thoracic fibres—into the inner border of the acromion process, and the upper border of the spine of the scapula; and (3) the lower thoracic fibres, by a triangular flat tendon, beneath which a bursa is placed—into a rough tuberosity at the base of the spine of the scapula (Fig. 299, p. 383). The fibres inserted into the clavicle, acromion, and the upper border of the spine of the scapula, spread over the adjacent subcutaneous surfaces of these bones for a variable distance.

The occipital portion of the muscle may be in the form of a separate slip, or may be entirely absent.

The trapezius is superficial in its whole extent. Its upper lateral border forms the posterior limit of the posterior triangle of the neck. The lower lateral border, passing over the upper edge of the latissimus dorsi and the vertebral border of the scapula, forms a boundary of the so-called *triangle of auscultation* completed below by the latissimus dorsi, and externally by the vertebral border of the scapula. This space is partly filled up by the rhomboideus major. The deep surface of the muscle is in contact with the complexus, splenius capitis, omohyoid, supraspinatus, levator anguli scapulæ, rhomboidei, serratus posticus superior, erector spinæ, and latissimus dorsi muscles. The spinal accessory nerve, branches of the cervical plexus (C. 3. 4.), and of the superficial cervical and posterior scapular arteries, are situated beneath the muscle.

The **latissimus dorsi** is a large triangular muscle occupying the lower part of the back. It has a triple origin. The greater part of the muscle arises—(1) from

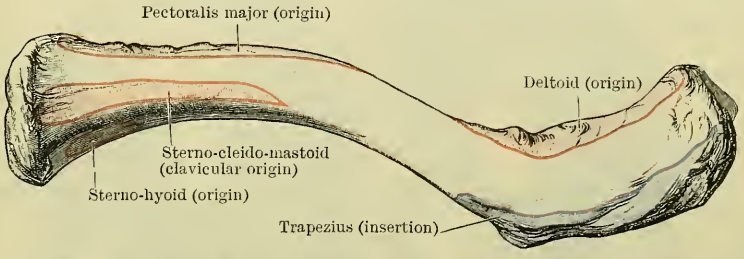


Fig. 243.—Muscle-Attachments to the Clavicle (Upper Surface).

the *vertebral aponeurosis* (posterior layer of the lumbar fascia or aponeurosis of the latissimus dorsi). This is a thick membrane which conceals the erector spinæ in the lower part of the back. Through it the latissimus dorsi gains attachment to the spines of the lower six thoracic vertebræ, the spines of the lumbar vertebræ, and the tendon of the erector spinæ with which the aponeurosis blends below. It also arises more externally by fleshy fibres from the posterior part of the iliac crest. From this origin the muscle is directed upwards and outwards, its fibres converging to the lower angle of the scapula. In relation to its upper and outer borders additional fibres arise. (2) *Along the outer border* muscular slips arise from the lower three or four ribs, inter-digitating with the origins of the obliquus externus abdominis. (3) As *the upper border* of the muscle passes horizontally over the lower angle of the scapula, an additional fleshy slip usually takes origin from this part of the bone to join the muscle on its deep surface (Fig. 245, p. 321).

Beyond the lower angle of the scapula the latissimus dorsi, greatly narrowed, curves spirally round the teres major muscle, and forms the prominence of the posterior axillary fold. It ends in a ribbon-like tendon, closely adherent at first to the teres major, which is **inserted** into the floor of the bicipital groove of the humerus, extending for about three inches below the lower and outer part of the lesser tuberosity (Fig. 253, p. 329). It is placed behind the coraco-brachialis and biceps, and the axillary vessels and nerves, and in front of the insertion of the teres major, from which it is separated by a bursa.

In the back the latissimus dorsi is superficial, except in its upper part, which is concealed by the trapezius. It lies upon the lumbar fascia, serratus posticus inferior, the ribs, and lower angle of the scapula, and at its borders two triangular spaces are formed; at the upper border is the so-called *triangle of auscultation*; at the outer border is the *triangle of Petit*, a small space bounded by the iliac crest, the latissimus dorsi, and the obliquus externus abdominis. This is the site of an occasional lumbar hernia.

The **levator anguli scapulæ** (levator scapulæ) is a strap-like muscle, arising by tendinous slips from the posterior tubercles of the transverse processes of the first three or four cervical vertebræ, between the attachments of the scalenus medius in front and the splenius colli behind. It is directed downwards along the

side of the neck, to be **inserted** into the vertebral border of the scapula in its upper fourth, from the superior angle to the spine (Fig. 245, p. 321). It is concealed in its upper third by the sterno-mastoid and deep muscles of the neck. In its middle third it occupies the floor of the posterior triangle. In its lower third it is again

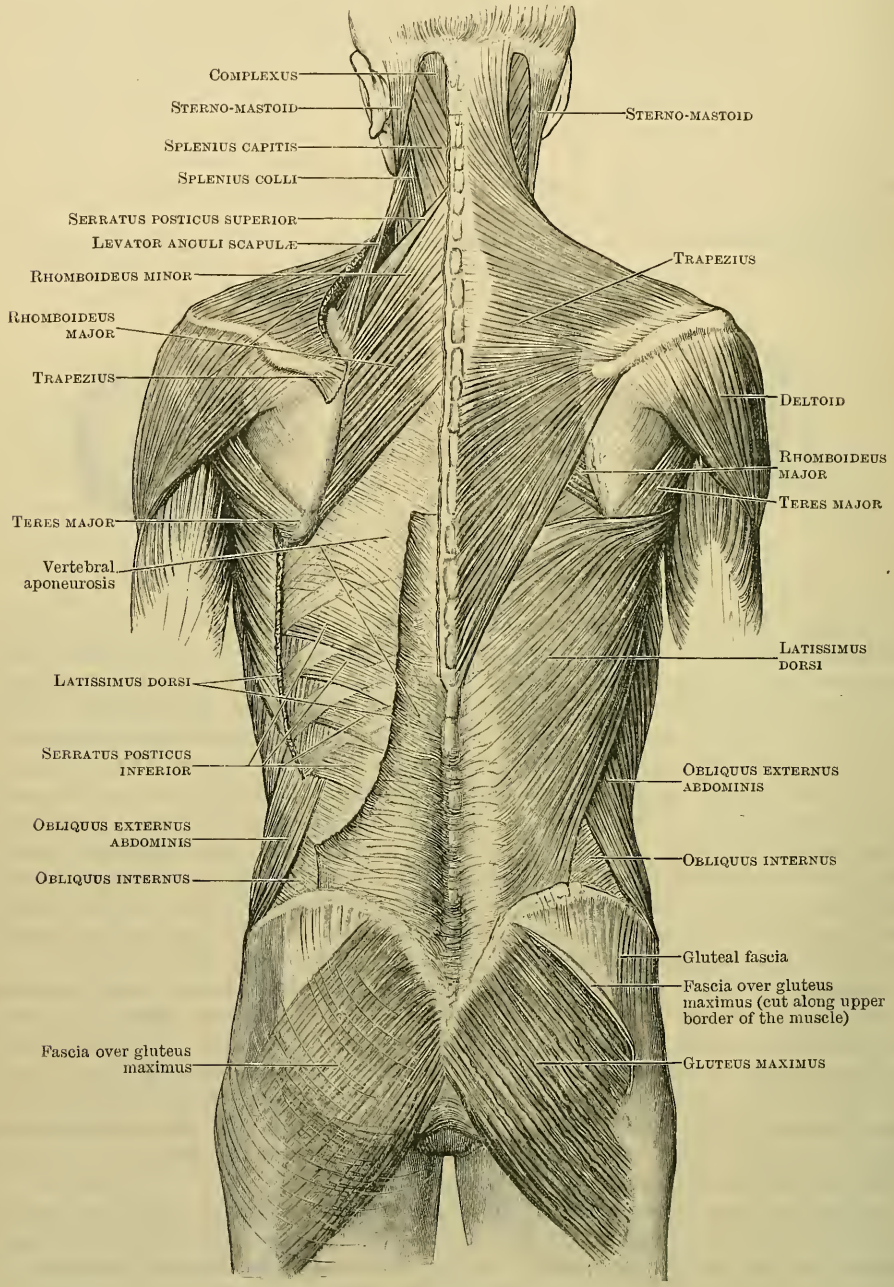


Fig. 244.—Superficial Muscles of the Back.

hidden from view by the trapezius. It conceals the splenius colli and cervicalis ascendens muscles.

The **rhomboideus minor** may be regarded as a separated slip of the rhomboideus major, with which it is often continuous. It **arises** from the *ligamentum nuchæ* and the spines of the seventh cervical and first thoracic vertebræ. Passing obliquely downwards and outwards, it is **inserted** into the vertebral border of the

scapula below the levator anguli scapulæ muscle, and opposite to the base of the spine (Fig. 245, p. 321).

The **rhomboideus major** arises from the spinous processes of the thoracic vertebræ from the second to the fifth inclusive, and from the corresponding supraspinous ligaments. Passing downwards and outwards, it is **inserted** below the rhomboideus minor into the vertebral border of the scapula, between the spine and the lower angle (Fig. 245, p. 321). The muscle is only inserted directly into the scapula by means of its lower fibres. Its upper part is attached to a membranous band, which, connected for the most part by loose areolar tissue to the vertebral border of the scapula, is fixed to the bone at its extremities, above near the base of the spine, and below at the inferior angle.

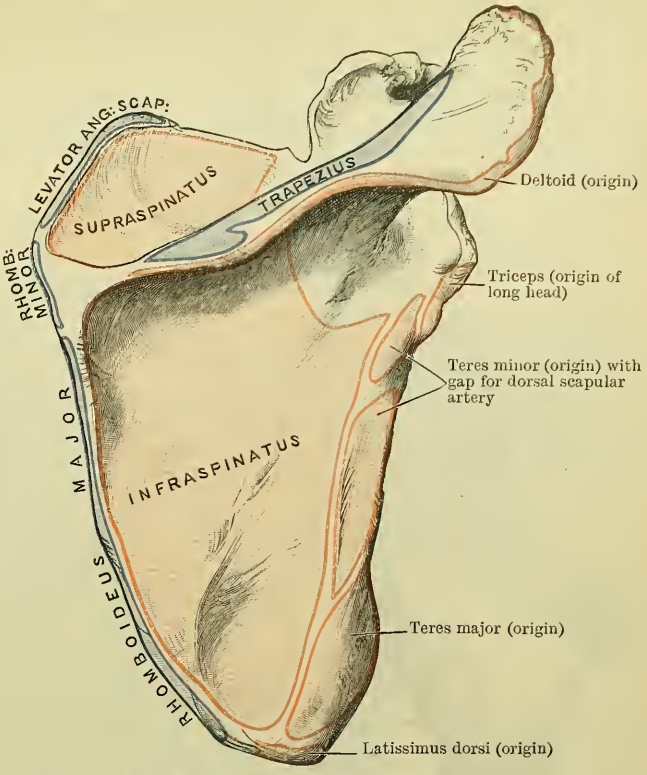


FIG. 245.—MUSCLE-ATTACHMENTS TO THE SCAPULA (Posterior Surface).

The rhomboid muscles are concealed for the most part by the trapezius. The lower part of the rhomboideus major is superficial in the *triangle of auscultation*. The muscles cover the serratus posticus superior and vertebral aponeurosis.

THE FASCIÆ AND MUSCLES OF THE PECTORAL REGION.

FASCIÆ.

The **superficial fascia** of the chest usually contains a quantity of fat, in which the mamma is embedded. The origin of the platysma myoides muscle lies beneath its upper part.

The **deep fascia** is attached above to the clavicle, and internally to the sternum. Below it is continuous with the fascia of the abdominal wall. It gives origin to the platysma myoides, and invests the pectoralis major. At the outer border of the great pectoral muscle it is thickened, and forms the floor of the axillary space (**axillary fascia**), continued posteriorly on to the posterior fold of the axilla (teres major and latissmus dorsi), and externally into connexion with the deep fascia of the arm.

Costo-Coracoid Membrane.—Beneath the pectoralis major a deeper stratum of fascia invests the pectoralis minor muscle. At the upper border of this muscle it forms the costo-coracoid membrane, which passes upwards to the lower border of the subclavius muscle, where it splits into two layers, attached in front of and behind that muscle to the borders of the under surface of the clavicle. The membrane traced inwards along the subclavius muscle is attached to the first costal cartilage; passing outwards along the upper border of the pectoralis minor it reaches the coracoid process. The part of the membrane extending directly between the first

costal cartilage and the coracoid process is thickened and forms the **costo-coracoid ligament.** The costo-coracoid membrane is otherwise thin and of comparatively small importance. It is pierced by the cephalic vein, thoracic axis artery and vein, and branches of the external anterior thoracic nerve. By its deep surface it is connected to the sheath of the axillary vessels.

At the lower border of the pectoralis minor there is a further extension of the deep fascia beneath the pectoralis major. It passes downwards to join the fascia forming the floor of the axilla, and is continued externally into the fascia covering the biceps and coraco-brachialis muscles.

MUSCLES OF THE PECTORAL REGION.

The anterior muscles connecting the upper limb to the axial skeleton comprise the pectoralis major, pectoralis minor, subclavius, serratus magnus, and sterno-cleido-mastoid. The last is described in a later section.

The **pectoralis major** is a large fan-shaped muscle **arising** in three parts: (1) *a clavicular portion* arising from the front of the clavicle in its inner half or two-thirds (Figs. 248, p. 324, and 243, p. 319); (2) *a costo-sternal portion,* the largest part of the muscle, arising from the anterior surface of the pre-sternum and meso-sternum by tendinous fibres decussating with those of the opposite muscle (Fig. 246, p. 322); and more deeply from the cartilages of the first six ribs; (3) *an abdominal portion,* a small and separate slip, arising from the aponeurosis of the obliquus externus muscle. The abdominal slip, at first separate, soon merges with the costo-sternal portion, but a distinct interval usually remains between the two first-named parts of the muscle. The fibres converge towards the upper part of the arm, and are inseparably blended at a point half an inch from their insertion into the humerus. The muscle is **inserted** into (1) the outer border of the bicipital groove of the humerus, extending upwards to the great tuberosity, and blending externally with the insertion of the deltoid, internally with the insertion of the latissimus dorsi (Fig. 253, p. 329); (2) from the upper border of the insertion a membranous band extends upwards to the capsule of the shoulder-joint, enveloping at the same time the tendon of the biceps; and (3) from the lower border a band of fascia passes downwards to join the fascia of the arm.

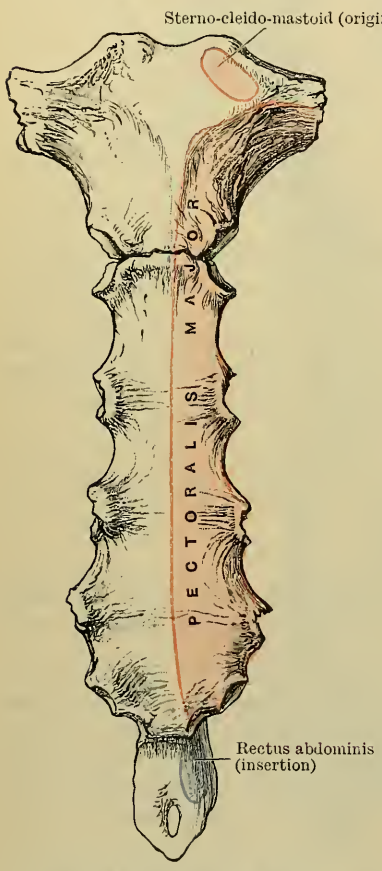


Fig. 246.—Muscle-Attachments to the Front of the Sternum.

The arrangement of the fibres of the muscle at its insertion is peculiar. The muscle is twisted on itself, so that the lower (*costo-sternal*) fibres are directed upwards and outwards behind the upper (*clavicular*) part of the muscle; in consequence the clavicular part is attached to the humerus lower down than the costo-sternal portion, and is inserted also into the fascia of the arm. The twisting of the fibres is specially found in the lower costo-sternal fibres of the muscle and the abdominal fibres. These curve upwards behind the upper costo-sternal fibres, and are inserted highest to the shaft of the humerus, helping to form the fascial expansion which extends upwards over the biceps tendon to the capsule of the shoulder-joint. In this way a bilaminar tendon is produced united

along its lower border; and consisting of a superficial lamina formed by the upper costo-sternal fibres, blending for the most part with the tendon of the clavicular portion; and a deep lamina, composed of the twisted lower costo-sternal and abdominal fibres. The disposition of the muscular fibres at their insertions is the

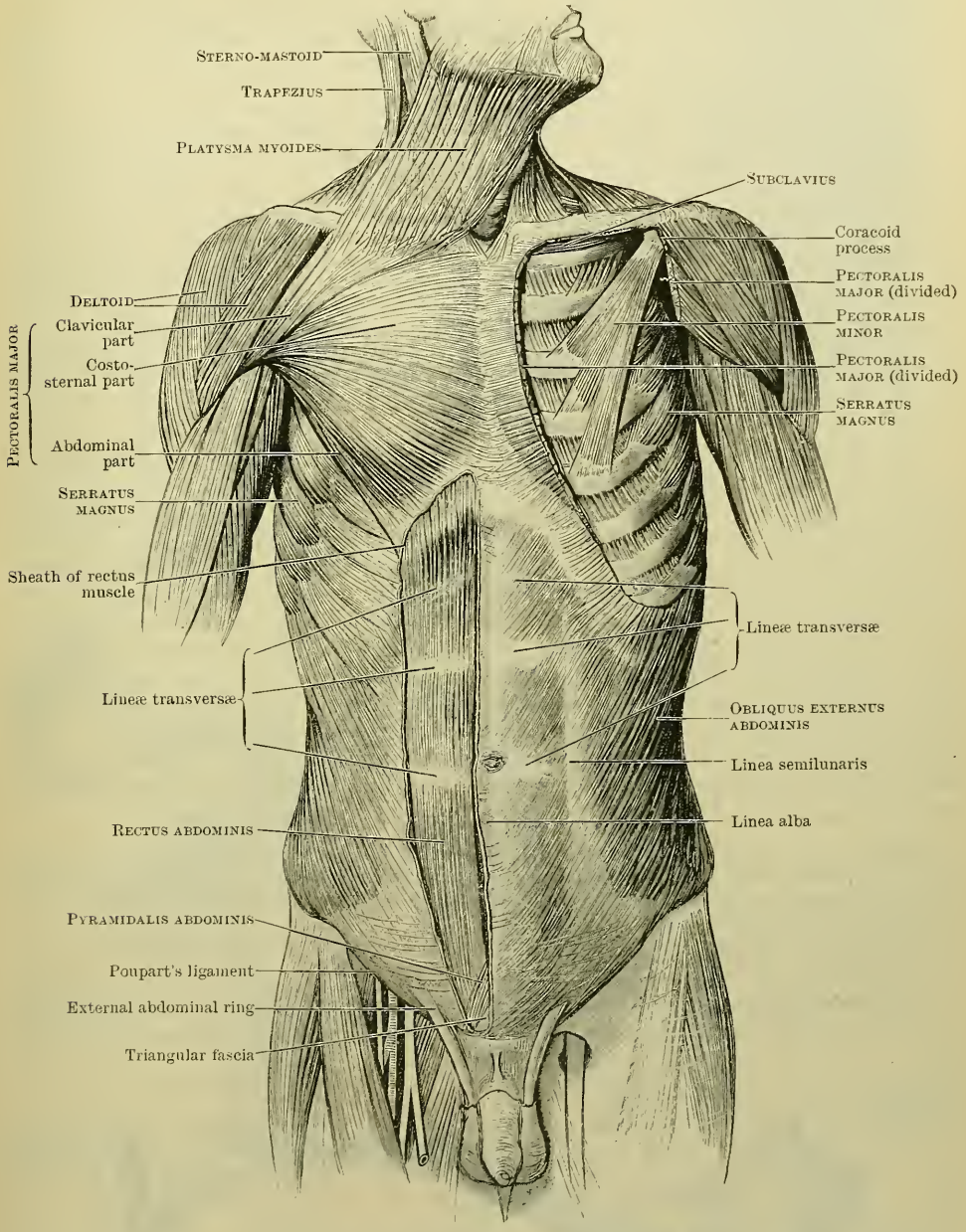


Fig. 247.—Anterior Muscles of the Trunk.

reason for the application of the terms *portio attollens* to the clavicular portion, and *portio deprimens* to the costo-sternal and abdominal portions of the muscle.

Placed superficially on the chest wall, the pectoralis major forms the front wall of the axilla, and by its lower or outer border, the anterior fold of the space. Its upper border is separated from the edge of the deltoid muscle by an interval in which lie the cephalic vein and humeral artery. Its deep surface is in relation with the ribs and intercostal muscles, the costo-coracoid membrane and

the structures piercing it, the pectoralis minor, the axillary vessels, and the nerves of the brachial plexus.

Sternalis muscle.—The sternalis is an occasional muscle placed, when present, parallel to the sternum upon the sterno-costal origin of the pectoralis major. It has attachments which are very variable both above and below, to the costal cartilages, sternum, rectus sheath, sterno-mastoid, and pectoralis major. Its **nerve-supply** is from one or both of the anterior thoracic nerves. In certain rare cases it has been said to be innervated by intercostal nerves. It is present in 4·4 cases out of 100, and it is slightly more frequent in the male than in the female. It has been regarded by different observers as (1) a vestige of the panniculus carnosus, (2) a homologue of the sterno-mastoid, or (3) a displaced slip of the pectoralis major.

Chondro-epitrochlearis, dorso-epitrochlearis, axillary arches, costo-coracoideus.—One or other of the above-named slips is occasionally present, crossing the floor of the axilla in the interval between the latissimus dorsi and the pectoralis major. They take **origin** from the costal cartilages, ribs, or borders of the pectoralis major (*chondro-epitrochlearis*, *axillary arches*, *costo-coracoideus*), or from the border of the latissimus dorsi (*dorso-epitrochlearis*, *axillary arches*, *costo-coracoideus*). Their **insertion** is variable. The *chondro-epitrochlearis* and *dorso-epitrochlearis* are inserted into the fascia of the arm on the inner side, the internal intermuscular septum, or the internal condyle of the humerus. The *axillary arches* are inserted into the border of the pectoralis major, the fascia of the arm, or the coraco-brachialis or biceps muscle. The *costo-coracoideus*, arising from the ribs or the aponeurosis of the obliquus externus, or detaching itself from the border of the pectoralis major or latissimus dorsi, is attached to the coracoid process, alone or along with one of the muscles attached to that bone. These variable slips of muscle are supplied by the internal anterior thoracic nerve, the lesser internal cutaneous nerve, or the intercosto-humeral.

The **pectoralis minor** is a narrow, flat, triangular muscle. It **arises** from (1) the outer surfaces and upper borders of the third, fourth, and fifth ribs near their anterior ends, and (2) from the fascia covering the third and fourth intercostal spaces between these ribs. It may have an additional origin from the second rib (Fig. 330, p. 420); and that from the fifth rib is often absent. Directed obliquely outwards and upwards, it is **inserted** by a short, flat tendon into the outer half of the anterior (inner) border and upper surface of the coracoid process (Fig. 250, p. 325), and usually also into the conjoint origin of the biceps and coraco-brachialis. It is wholly concealed by the pectoralis major, except when the arm is raised, when the outer border of the muscle becomes superficial. It enters into the formation of the front wall of the axilla, and gives attachment along its upper border to the costo-coracoid membrane. It crosses the axillary vessels and the cords of the brachial plexus, and is pierced by branches of the anterior thoracic nerves.

Either in part or wholly the pectoralis minor may pass over the coracoid process of the scapula, separated from it by a bursa, to be inserted into the coraco-acromial ligament, or the acromion process; or piercing the coraco-acromial ligament, it may be attached to the capsule of the shoulder-joint (coraco-humeral ligament).

Pectoralis minimus.—This is a slender slip, rarely present, which extends between the first costal cartilage and the coracoid process.

The **subclavius muscle** **arises** from the upper surface of the first costal cartilage in front of the costo-clavicular ligament, and from the upper surface of the

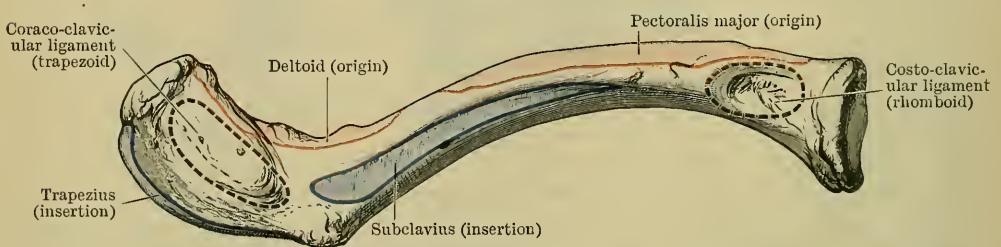


FIG. 248.—MUSCLE-ATTACHMENTS TO THE CLAVICLE (Under Surface).

distal end of the first rib (Fig. 330, p. 420). It is **inserted** into a groove in the middle third of the under surface of the clavicle (Fig. 248, p. 324). The muscle is invested by the fascia which forms the costo-coracoid membrane, and is concealed by the clavicle and the clavicular origin of the pectoralis major.

The **sterno-clavicularis** is a small separate slip, rarely present, extending beneath the pectoralis major from the upper part of the sternum to the clavicle.

The **serratus magnus** (m. serratus anterior) is a large curved quadrilateral muscle occupying the side of the chest and inner wall of the axilla. It **arises** by fleshy slips from the external aspect of the upper eight and occasionally (as in the figure) from nine ribs. The first slip is a double one, arising from the first two ribs and the fascia covering the intervening space (Fig. 330, p. 420). The **insertion** of the muscle is threefold. (1) The first portion of the muscle (from the first and second ribs) is directed backwards to be inserted into the ventral aspect of the upper angle of the scapula. (2) The next three slips of the muscle (from the second, third, and fourth ribs) are inserted into the vertebral border of the scapula. (3) The last four slips (from the fifth, sixth, seventh, and eighth ribs) are directed obliquely upwards and backwards, to be inserted on the ventral aspect of the lower angle of the scapula (Fig. 250, p. 325).

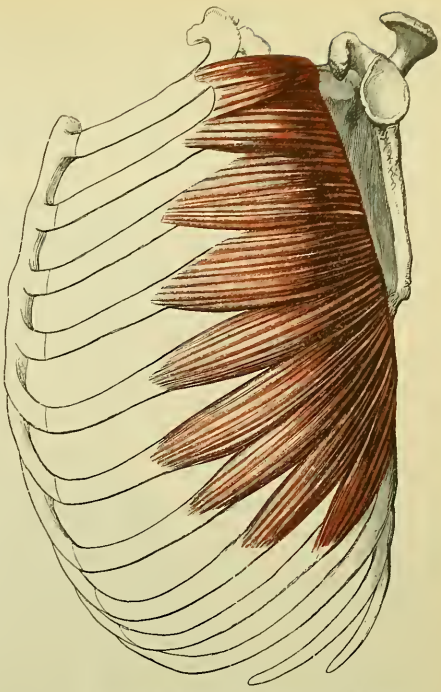


Fig. 249.—The Serratus Magnus Muscle.

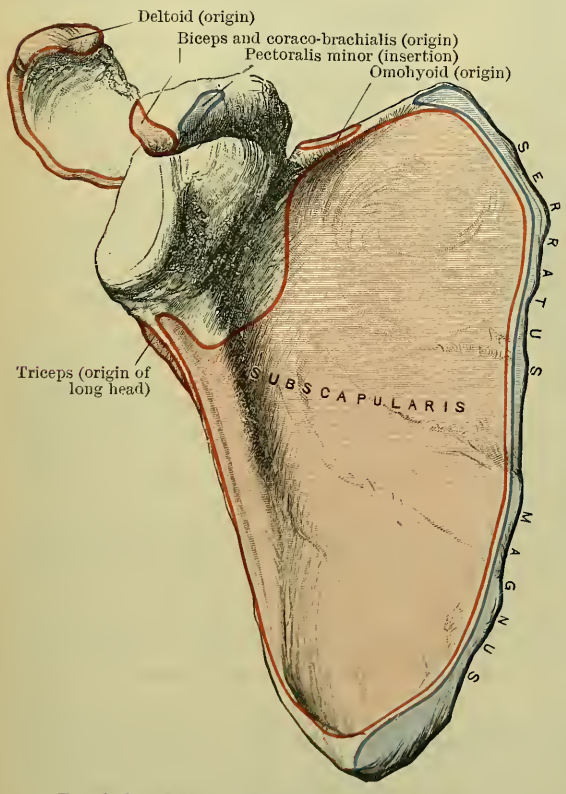


Fig. 250.—Muscle-Attachments to the Scapula (Anterior Aspect).

The external surface of the muscle is partly superficial below the axillary space, on the side wall of the chest, where its slips of origin are seen interdigitating with those of the obliquus externus abdominis. Higher up it forms the inner wall of the axilla, and is in contact with the pectoral muscles in front and the subscapularis behind. Its upper border appears in the floor of the posterior triangle, and over it the axillary artery and the cords of the brachial plexus pass in their course through the armpit. The lower border is oblique, and is in contact with the latissimus dorsi muscle. The deep surface of the muscle is in contact with the chest wall, so that the serratus magnus along with the subscapularis muscle separates the scapula from the ribs. The muscle may extend higher than usual, so as to be continuous in the neck with the levator anguli scapulæ.

Nerve-Supply.

The nerves supplying the muscles connecting the upper limb to the trunk are given in the following table :—

Muscles.	Nerves.	Origin.
Trapezius	Spinal accessory nerve	Spinal Cord
	Cervical plexus	C. 3. 4.
Latissimus dorsi	Long subscapular	C. 6. 7. 8.
Levator scapulæ	Cervical plexus	C. 3. 4.
	Posterior scapular	C. 5.
Rhomboidei	Posterior scapular	C. 5.
Pectorales	External anterior thoracic	C. 5. 6. 7.
	Internal „ „	C. 8. T. 1.
Subclavius	Brachial plexus	C. 5. 6.
Serratus magnus	Posterior thoracic	C. 5. 6. 7.

Actions.

The muscles of this group (together with the sterno-cleido-mastoid and omohyoid muscles) act for the most part in the movements of the shoulder girdle at the sterno-clavicular and acromio-clavicular joints. At the former joint they produce the various movements of the clavicle on the sternum, and cause the shoulder to move in an arc the centre of which is the sterno-clavicular joint. At the acromio-clavicular articulation they produce a rotation of the scapula on the clavicle, and a consequent alteration in the direction of the glenoid fossa. At the same time the several muscles are agents in other equally important movements, when the shoulder girdle is fixed ; movements of the head and neck ; movements of the trunk and ribs ; and, in addition in the case of the pectoralis major and latissimus dorsi, important movements of the arm at the shoulder-joint.

1. Movements of the Shoulder Girdle.—The action of this group of muscles on the shoulder girdle (mainly corresponding to movements at the sterno-clavicular joint) may be expressed in the following table :—

a. **Movement in a Vertical Plane.**		*b.* **Movement in a Horizontal Plane.**	
Elevation.	**Depression.**	**Forwards.**	**Backwards.**
Trapezius (upper fibres)	Trapezius (lower fibres)	Serratus magnus	Trapezius
Levator scapulæ	Subclavius	Pectoralis major	Rhomboidei
Rhomboidei	Pectoralis minor	Pectoralis minor	Latissimus dorsi
Sterno-mastoid	Latissimus dorsi		
Omohyoid	Pectoralis major (lower fibres)		
		c. **Rotation**—a combination of these muscles.	

2. Movements of the scapula on the clavicle produce an alteration of the direction of the glenoid fossa of the scapula, and are accompanied by movements, inwards or outwards, forwards or backwards, of the inferior angle of the scapula. By the combined action of the muscles acting upon the shoulder girdle a **rotatory movement** of the scapula at the acromio-clavicular joint is effected, by which the relation of the glenoid fossa to the head of the humerus is preserved in movements of the arm.

3. In forced inspiration, the sterno-mastoid, trapezius, levator scapulæ, rhomboidei, subclavius, omohyoid, serratus magnus, pectoral muscles, and latissimus dorsi, acting together, raise and fix the shoulder girdle ; while those of them which have costal attachments—subclavius, pectoral muscles, serratus magnus, and latissimus dorsi, simultaneously elevate the ribs and expand the thorax.

4. Lateral flexion and rotation of the spine in the neck is effected partly by the action of the trapezius, levator scapulæ, and rhomboid muscles (with the shoulder fixed). The latissimus dorsi and pectoralis major act in climbing in a similar way, raising up the trunk towards the shoulder.

5. Action on the Upper Limb.—By reason of their insertion into the humerus the pectoralis major and latissimus dorsi muscles assist the movements of the upper limb. Acting together, the two muscles depress the shoulder, and draw the arm to the side of the body, at the same time rotating the humerus inwards. The two parts of the pectoralis major have slightly different actions on the humerus. The clavicular part of the muscle (*portio attollens*) draws the arm inwards and upwards ; the costo-sternal part of the muscle (*portio deprimens*) draws it inwards and downwards. The latissimus dorsi acting alone, besides rotating the limb, draws it inwards and backwards, as in the act of swimming.

FASCIÆ AND MUSCLES OF THE SHOULDER.

The **deep fascia** covering the scapular muscles presents no feature of special importance. Attached to the clavicle, acromion, and scapular spine, it is thin over the deltoid muscle. Below the deltoid it is thicker; it encases and gives origin to the infraspinatus muscle, and is continuous with the fasciæ of the axilla and the back.

Muscles.

The **muscles** proper to the shoulder comprise the deltoid, supraspinatus, infraspinatus, teres minor, teres major, and subscapularis. They surround, and along with other muscles, act on the shoulder-joint.

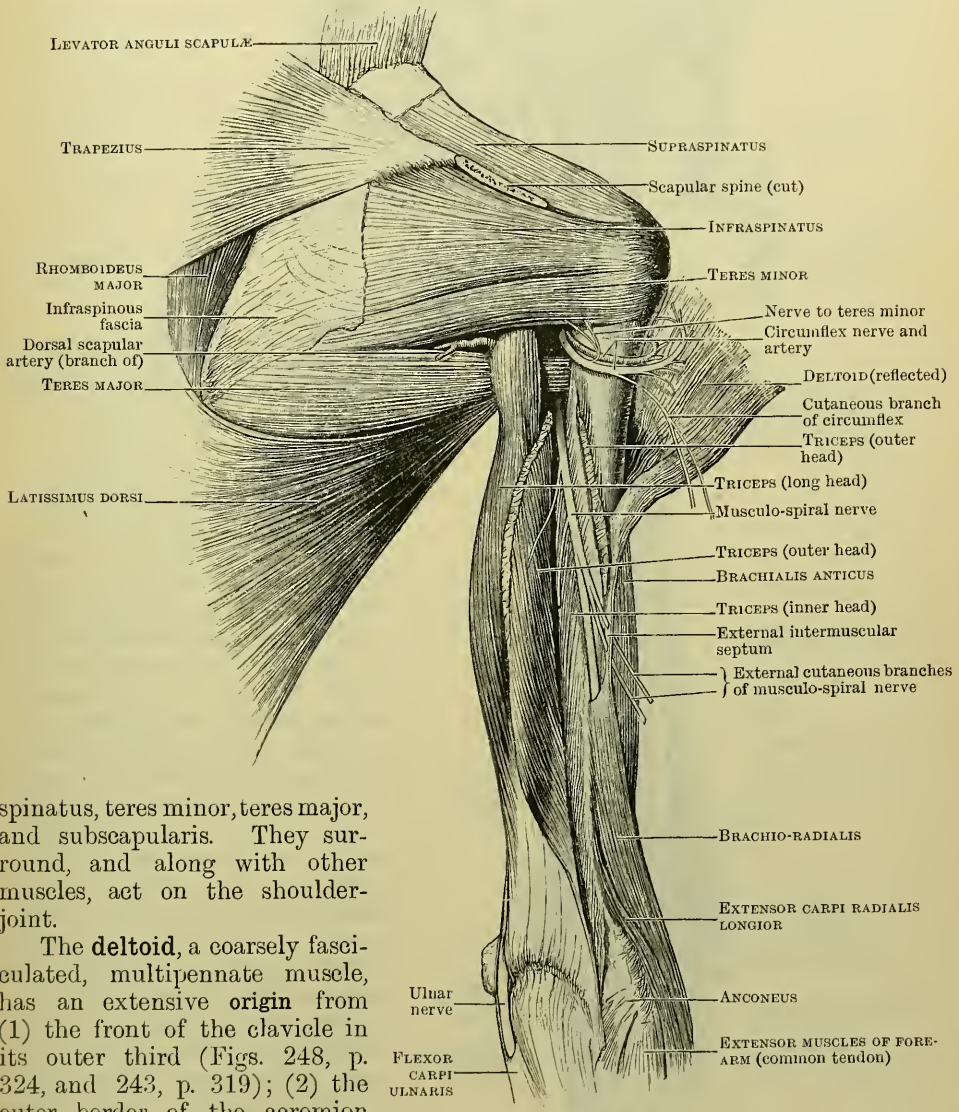


Fig. 251.—Deltoid Region and Back of the Arm.

The **deltoid**, a coarsely fasciculated, multipennate muscle, has an extensive **origin** from (1) the front of the clavicle in its outer third (Figs. 248, p. 324, and 243, p. 319); (2) the outer border of the acromion process; (3) the lower edge of the free border of the spine of the scapula (Figs. 254, p. 330, and 250, p. 325); and (4) from the deep fascia covering the infraspinatus muscle. Its origin embraces the insertion of the trapezius. The fibres of the muscle converge to the outer side of the shaft of the humerus, to be **inserted** into a well-marked V-shaped impression above the spiral groove (Figs. 257 and 258, p. 335). The insertion is partly united with the tendon of the pectoralis major. The deltoid is superficial in its whole extent, and forms the prom-

inence of the shoulder. Its anterior border is separated from the pectoralis major by a narrow interval, in which the cephalic vein and humeral artery are placed. The deep surface of the muscle is separated by a bursa from the capsule of the shoulder-

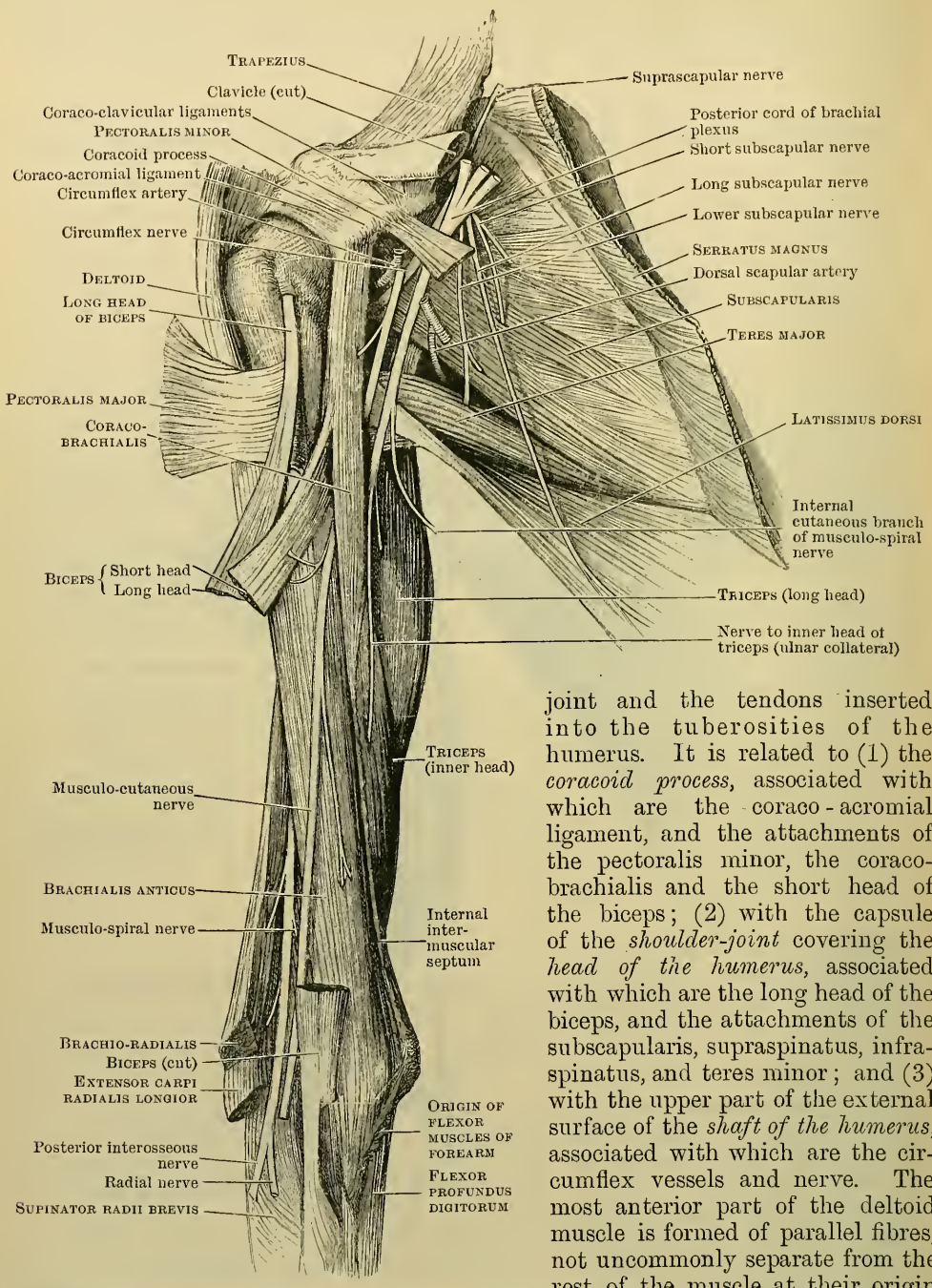


Fig. 252.—The Posterior Wall of the Axilla and the Front of the Arm (the biceps being divided).

joint and the tendons inserted into the tuberosities of the humerus. It is related to (1) the *coracoid process*, associated with which are the coraco-acromial ligament, and the attachments of the pectoralis minor, the coraco-brachialis and the short head of the biceps; (2) with the capsule of the *shoulder-joint* covering the *head of the humerus*, associated with which are the long head of the biceps, and the attachments of the subscapularis, supraspinatus, infraspinatus, and teres minor; and (3) with the upper part of the external surface of the *shaft of the humerus*, associated with which are the circumflex vessels and nerve. The most anterior part of the deltoid muscle is formed of parallel fibres, not uncommonly separate from the rest of the muscle at their origin from the clavicle. These fibres may be continuous with the trapezius over the clavicle. The most posterior part arises by a fascial origin from the spine of the scapula and the fascia over the infraspinatus muscle. These portions are attached respectively to the front and back of the main tendon of insertion. The intermediate fibres are multipennate, attached above and below to three or four

septal tendons, which extend for a variable distance from the origin and insertion of the muscle.

The **supraspinatus** arises by fleshy fibres from the supraspinous fossa (except near the neck of the bone) and from the deep fascia over it (Fig. 254, p. 330). It is directed outwards under the acromion process and coraco-acromial ligament to be **inserted** by a broad thick tendon into the uppermost facet on the great tuberosity of the humerus, and into the capsule of the shoulder-joint (Fig. 253, p. 329).

The muscle is entirely concealed from view by the trapezius, the acromion process, and the deltoid muscle. It covers the neck of the scapula, the suprascapular vessels and nerves, and the upper surface of the capsule of the shoulder-joint.

The **infraspinatus** arises from the infraspinous fossa of the scapula (excepting near the neck of the bone and the flat surface along the axillary border) and from the thick fascia over it (Fig. 254, p. 330). The fibres of the muscle converge to the neck of the scapula; and are **inserted** by tendon into the middle facet on the great tuberosity of the humerus, and into the capsule of the shoulder-joint (Fig. 258, p. 335). A bursa separates the muscle from the neck of the scapula, and in a minority of cases communicates with the synovial cavity of the shoulder-joint.

The upper part of the muscle is hidden from view by the deltoid. Its lower part is superficial, and its outer border is in contact with the teres minor. Near its insertion it crosses the neck of the scapula and the back of the capsule of the shoulder-joint.

The **teres minor** is a small muscle, **arising** by fleshy fibres from the upper two-thirds of the flat surface on the dorsal aspect of the axillary border of the scapula, and from fascial septa separating it from the infraspinatus and teres major muscles (Fig. 254, p. 330). Lying alongside the outer border of the infraspinatus, it is **inserted** under cover of the deltoid by a thick flat tendon into the lowest of the three facets on the great tuberosity of the humerus and into the capsule of the shoulder-joint, and by fleshy fibres into the posterior aspect of the surgical neck and shaft of the humerus, below the tuberosity for about an inch (Fig. 258, p. 335). It is separated from the teres major by the scapular head of the triceps, and by the posterior circumflex vessels and the circumflex nerve. Its origin is pierced by

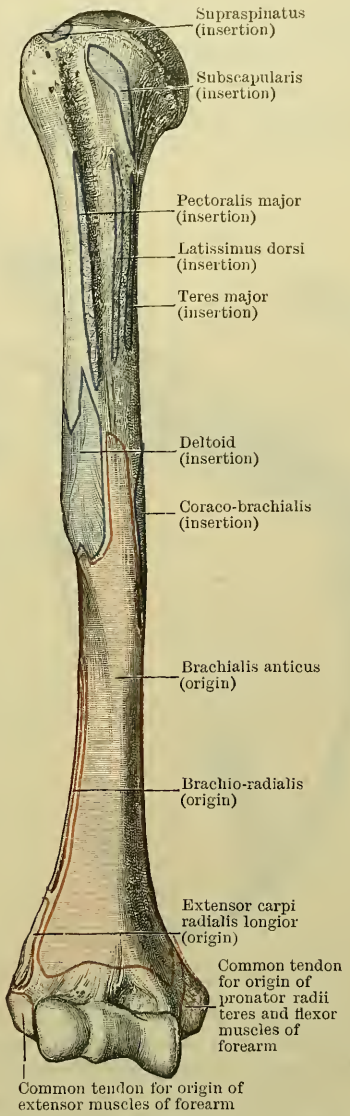


FIG. 253.—MUSCLE-ATTACHMENTS TO THE FRONT OF THE HUMERUS.

the dorsal scapular artery. The muscle is invested by the deep fascia enclosing the infraspinatus, and is sometimes inseparable from that muscle.

The **teres major** is much larger than the preceding muscle. It **arises** by fleshy fibres from the lower third of the flat surface on the dorsum of the scapula along its axillary border (except for a small area at the lower angle), and from fascial septa, which separate it on the one side from the subscapularis, and on the other from the infraspinatus and teres minor (Fig. 254, p. 330). The muscle is directed along the axillary border of the scapula to the front of the shaft of the humerus, where it is **inserted** by a broad flat tendon into the inner border of the bicipital groove internal to the latissimus dorsi muscle (Fig. 257, p. 335). Just before its insertion it is closely adherent to the tendon of the latissimus dorsi.

The teres major helps to form the posterior wall of the axilla. It lies below the subscapularis, and is in close relation with the latissimus dorsi muscle, which conceals its origin posteriorly, winds round its outer border, and partially separates its anterior surface from the axillary vessels and nerves. The muscle forms the lower boundary of a large triangular interval, bounded externally on the posterior wall of the axilla by the surgical neck of the humerus, and above by the borders of the subscapularis and teres minor muscles. The long head of the triceps passes behind the teres major and subdivides this space into two, a quadrilateral space limited by the triceps and surgical neck of the humerus for the passage of the circumflex nerve and posterior circumflex vessels, and a smaller triangular space bounded by the triceps, subscapularis, and teres major, for the dorsal scapular artery.

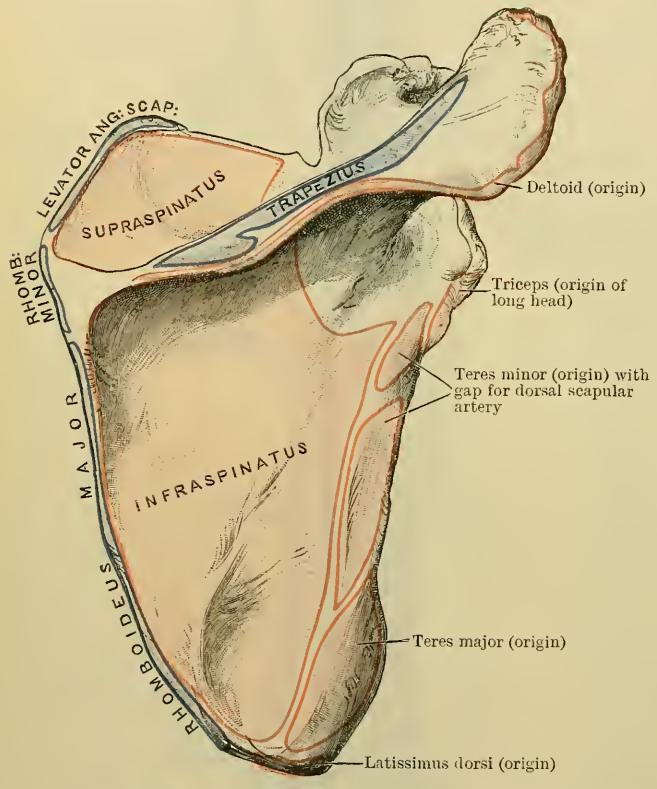


FIG. 254.—MUSCLE-ATTACHMENTS TO THE SCAPULA (Posterior Surface).

The **subscapularis** is a large triangular muscle occupying the venter of the scapula. It **arises** by fleshy fibres from the whole of the subscapular fossa and the groove along the axillary border, excepting the surfaces at the angles of the bone (Fig. 250, p. 325). Springing from several ridges in the fossa are septa projecting into the substance of the muscle, which increase the extent of its attachment. Converging to the head of the humerus, the muscular fibres are **inserted** by a broad, thick tendon into the lesser tuberosity of the humerus and into the capsule of the shoulder-joint, and by fleshy fibres into the surgical neck and the shaft of the humerus below the tuberosity for about an inch, under cover of the coraco-brachialis and short head of the biceps (Fig. 257, p. 335). This muscle forms the greater part of the posterior wall of the axilla. Its inner or anterior surface is in contact with the serratus magnus and the axillary vessels and nerves. Its deep surface is separated from the neck of the scapula by a bursa, which is in direct communication with the synovial cavity of the shoulder-joint. Its upper border passes beneath the coracoid process; its outer border is separated from the teres major by the posterior circum-

flex vessels and the circumflex nerve, the long head of the triceps muscle, and the dorsal scapular artery.

The **subscapularis minor** is an occasional muscle situated below the capsule of the shoulder-joint. It arises from the axillary border of the scapula below the subscapularis, and is inserted into the capsule of the joint or the upper part of the shaft of the humerus.

Nerve-Supply.

The muscles of this group are all supplied by the fifth and sixth cervical nerves, through nerves arising from posterior trunks of the brachial plexus.

Muscles.	Nerves.	Origin.
Deltoid, Teres minor	Circumflex	C. 5. 6.
Supraspinatus, Infraspinatus	Suprascapular	C. 5. 6.
Teres major	Lower subscapular	C. 5. 6.
Subscapularis	Lower and upper subscapular	C. 5. 6.

Actions.

The principal action of this group of muscles is on the shoulder-joint. They have also secondary actions in relation to movements of the trunk and limbs.

1. Movements at the Shoulder-Joint.

a. **Abduction.**	**Adduction.**	*b.* **Flexion** (Forwards).	**Extension** (Backwards).
Deltoid Supraspinatus	Teres major Teres minor Pectoralis major Latissimus dorsi Coraco-brachialis Biceps (short head) Triceps (long head) (Weight of limb)	Deltoid (anterior fibres) Subscapularis Pectoralis major Coraco-brachialis Biceps	Deltoid (posterior fibres) Teres major Infraspinatus Latissimus dorsi Triceps

c. **Rotation Outwards.**	**Rotation Inwards.**
Deltoid (posterior fibres) Infraspinatus Teres minor	Deltoid (anterior fibres) Teres major Pectoralis major Latissimus dorsi
d. **Circumduction**—combination of previous muscles.	

The various movements at the shoulder-joint are greatly aided by the muscles acting on the shoulder girdle. In raising the arm above the head, for instance, the humerus is brought to the horizontal position by the deltoid and supraspinatus, and the movement is continued by the elevators of the shoulder girdle. Again, in forward and backward movements at the shoulder-joint, great assistance is derived from muscles acting directly on the shoulder girdle—pectoralis minor and serratus magnus; trapezius and rhomboidei.

2. **In relation to the trunk and limbs,** the shoulder muscles, by fixing the humerus, have auxiliary power on the one hand in movements of the trunk, such as forced inspiration; on the other hand, acting along with muscles fixing the elbow-joint, they stiffen the limb so as to permit of the more refined movements of the wrist and fingers.

FASCIÆ AND MUSCLES OF THE ARM.

FASCIÆ.

The **superficial fascia** presents no features of importance. There is a bursa beneath it over the olecranon process, and occasionally another over the inner condyle of the humerus.

The **deep fascia** forms a strong tubular investment for the muscles on the front and back of the humerus. It is continuous above with the deep fascia of the shoulder and axilla, and is further strengthened by fibres derived from the insertions of muscles attached to the upper part of the humerus, viz., from the pectoralis major, latissimus dorsi, and deltoid. At the elbow it becomes continuous with the deep fascia of the forearm, and gains attachment to the condyles of the humerus and the olecranon process of the ulna; it is strengthened also by important bands associated with the insertions of the biceps in front and the triceps behind, to which reference will be made in the account of these muscles.

About the middle of the upper arm in front of the inner border, the deep fascia is perforated for the passage of the basilic vein and the internal cutaneous nerve.

The **intermuscular septa** are processes of the deep fascia attached to the supracondyloid or epicondylic ridges of the humerus. The **internal** and stronger **septum** is placed between the brachialis anticus in front and the inner head of the triceps behind, and gives origin to both. It extends upwards to the insertion of the coraco-brachialis (which is often continued into it), and the ulnar nerve and inferior profunda vessels pass down over its inner edge. The **external septum** is thinner. It separates the brachialis anticus and brachio-radialis in front from the inner and outer heads of the triceps behind, and gives origin to these muscles. It extends upwards to the insertion of the deltoid, and is pierced by the musculo-spiral nerve and superior profunda vessels.

MUSCLES.

The **coraco-brachialis** is a rudimentary muscle placed on the front and inner aspect of the arm. It **arises** in common with the short head of the biceps from the tip of the coracoid process of the scapula (Fig. 250, p. 325), and is commonly connected at its origin with the insertion of the pectoralis minor. The origin of the muscle is by fleshy fibres attached (1) to the tip of the coracoid process below and internal to the biceps tendon, and (2) to the tendon of the biceps itself. The muscle is partially subdivided into two parts by the musculo-cutaneous nerve, and ends in a flat tendon **inserted** into a faint linear impression about an inch in length on the middle of the inner border of the shaft of the humerus (Fig. 257, p. 335). It is often continued into the internal intermuscular septum.

The muscle lies on the inner side of the biceps, and is concealed at first by the deltoid and pectoralis major. In the lower part of its extent it is superficial, and forms a swelling beneath the skin on the inner side of the arm which serves as a guide to the axillary and brachial arteries.

The **coraco-brachialis** is the remains of a *threefold muscle*, of which only two elements are usually present in man, but of which in anomalous cases all the parts may be more or less fully developed. The passage of the musculo-cutaneous nerve through the muscle is an indication of its natural separation into two parts, which represent the persistent middle and inferior elements. The commonest variety is one in which the more superficial (inferior) part of the muscle extends farther down the arm than usual, so as to be inserted into the internal intermuscular septum, or even into the internal condyle of the humerus. A third slip (**coraco-brachialis superior** or **brevis, rotator humeri**) may more rarely be present, forming a short muscle **arising** from the root of the coracoid process, and **inserted** into the inner side of the humerus just below the capsule of the shoulder-joint.

The **biceps** (m. biceps brachii) is the large superficial muscle which lies on the front of the upper arm. It **arises** by two tendinous *heads*. (1) The **short head** (caput breve) is attached in common with the coraco-brachialis to the tip of the coracoid process of the scapula (Fig. 250, p. 325). Tendinous at first, this head forms a separate fleshy belly, which is united to the long head by an investment of the deep fascia.

(2) The **long head** (caput longum) arises by a round tendon from the supra-glenoid impression at the root of the coracoid process and from the glenoid ligament on either side. Its tendon traverses the cavity of the shoulder-joint, and emerging from the capsule beneath the transverse ligament (invested by a prolongation of the synovial membrane), it occupies the bicipital groove of the humerus, covered by a fascial prolongation of the tendon of the pectoralis major. In the upper arm it forms a fleshy belly united to that derived from the short head by an envelope of deep fascia.

The **insertion** of the muscle is likewise twofold. (1) The two bellies become connected with a strong *tendon*, attached deeply in the hollow of the elbow to the rough posterior portion of the bicipital tubercle of the radius (Figs. 264, p. 343, and 271, p. 351). A bursa separates the tendon from the anterior portion of the tubercle. (2) From the inner and anterior part of the tendon, and partly in continuity with the fleshy fibres of the muscle, a strong *membranous band* (the **semilunar** or **bicipital fascia**) extends downwards and inwards over the hollow of the elbow to join the deep fascia covering the origins of the flexor and pronator muscles of the forearm. Its upper part is thickened and can be felt subcutaneously as a crescentic border.

Except at its origin and insertion the biceps muscle is placed superficially on the front of the arm, concealing the brachialis anticus muscle and the musculo-cutaneous nerve. The brachial artery and median nerve lie along its inner border. The origin of the muscle is deeply placed under cover of the deltoid and pectoralis major. The tendon of insertion in the hollow of the elbow lies beneath the end of the brachial and the beginning of the radial artery. The bicipital fascia separates the brachial artery from the median basilic vein.

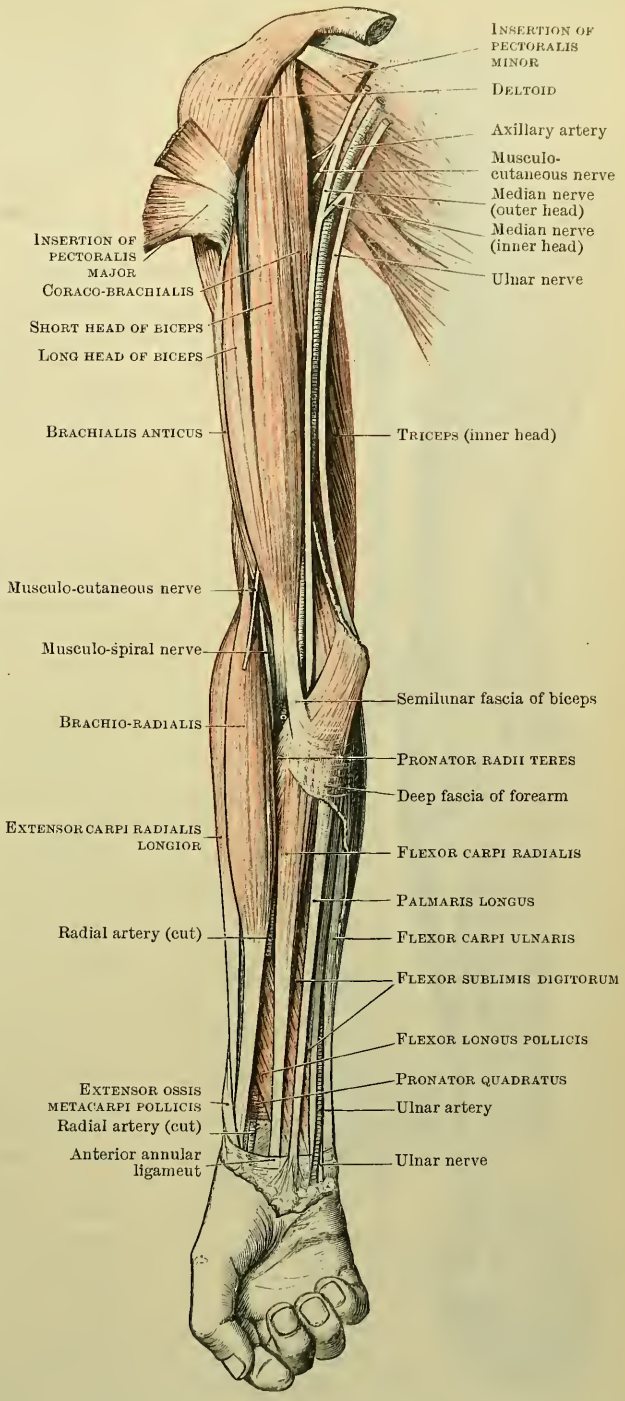


Fig. 255.—Superficial Muscles on the Front of the Arm and Forearm.

The **biceps** is an extremely variable muscle. Its chief anomalies are due to an increase or diminution in the number of origins. A third **head of origin** is common (10 per cent), and usually arises from the humerus, between the insertions of the deltoid and coraco-brachialis. Two or even three additional heads may be present at the same time. The long head of the muscle may be absent, or may take origin from the bicipital groove. The muscle may have an additional insertion into the internal condyle of the humerus, or into the fascia of the forearm.

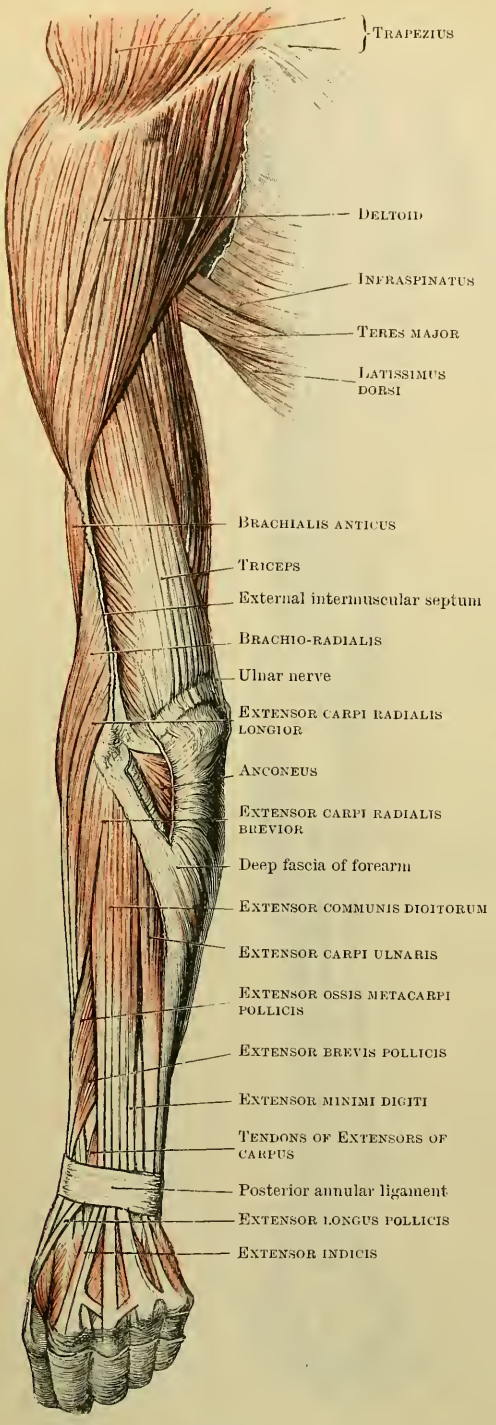


Fig. 256.—The Muscles on the Back of the Arm, Forearm, and Hand.

The **brachialis anticus** (m. brachialis) is a large muscle **arising** from the lower two-thirds of the front of the shaft of the humerus, and from the inter-muscular septum on each side (Figs. 257 and 258, p. 335). Clasping the insertion of the deltoid above, it ends below in a strong tendon **inserted** into the rough inferior surface of the coronoid process of the ulna and into the anterior surface of the shaft of the bone immediately below (Fig. 264, p. 343). A few of the deep fibres are inserted into the anterior ligament of the elbow-joint. The outer part of the muscle arising from the external epicondylic ridge and external intermuscular septum forms a slip more or less separate, which may be partially fused with the brachio-radialis muscle.

The brachialis anticus is almost wholly concealed from view by the biceps in front, the brachio-radialis externally, and the brachial vessels internally. It covers the elbow-joint, and forms part of the floor of the hollow of the elbow. It is separated from the brachio-radialis and extensor muscles of the carpus by the musculo-spiral nerve.

The **triceps** (m. triceps brachii) is the only muscle on the back of the arm. It **arises** by three heads: an outer and an inner head, from the humerus, and a middle or long head from the scapula. (1) The **middle, long** or **scapular head** (caput longum) begins as a strong tendon attached to a rough triangular surface on the axillary border of the scapula just below the glenoid fossa (Figs. 254, p. 330, and 250, p. 325). This gives rise to a fleshy belly which occupies the middle of the back of the arm. (2) The **outer head** (caput laterale) is attached by fibres, partly tendinous and partly fleshy, to the curved outer border of the humerus from the insertion of the teres minor above to the musculo-spiral groove below, and receives additional fibres from the back of the external intermuscular septum (Fig. 258, p. 335). This origin is thick above and becomes

linear below. Its fibres are directed downwards and inwards over the musculo-spiral groove and the inner head of the muscle to the tendon of insertion (3) The **inner head** (caput mediale) arises by fleshy fibres from an elongated triangular area on the back of the humerus, extending upwards to the level of the insertion of the teres major on the inner side, and downwards nearly to the margin of the olecranon fossa. (Fig. 258, p. 335). Externally it is limited above by the musculo-spiral groove;

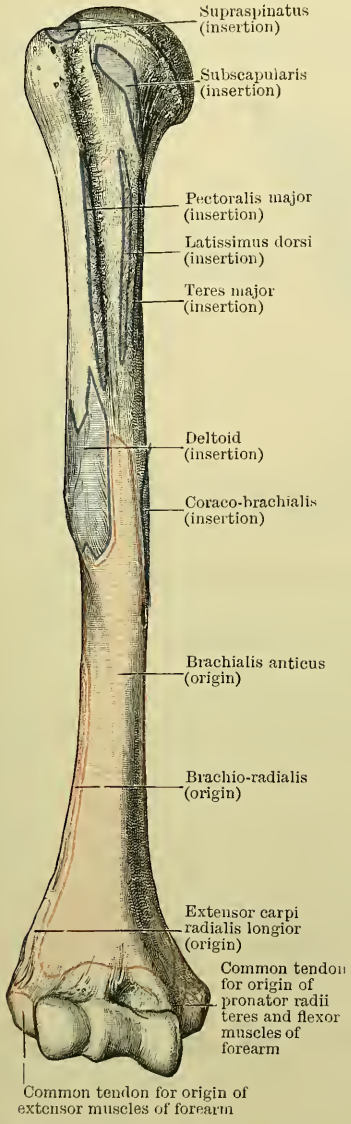


FIG. 257.—MUSCLE-ATTACHMENTS TO THE FRONT OF THE HUMERUS.

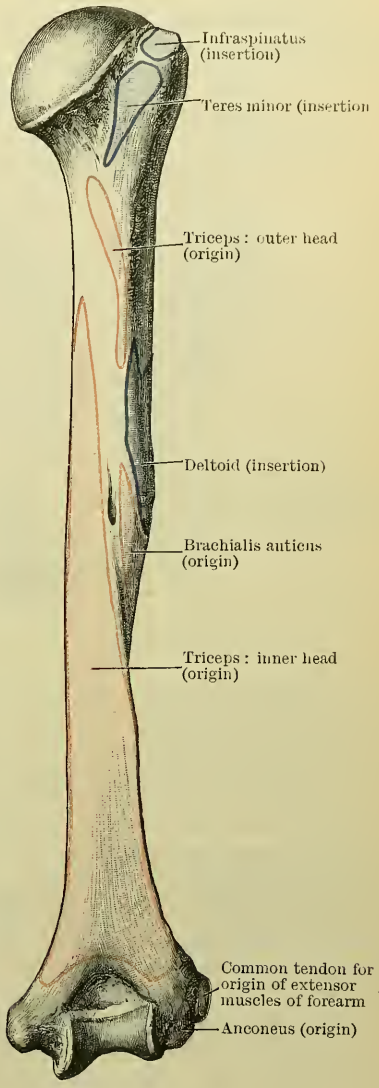


FIG. 258.—MUSCLE-ATTACHMENTS TO THE BACK OF THE HUMERUS.

and below it extends downwards on either side of the olecranon fossa almost to the condyles of the humerus. It also arises on each side from the intermuscular septa,—from the whole length of the internal septum, and from the part of the external septum which is below the passage of the musculo-spiral nerve.

The three heads of origin are **inserted** by a common tendon, broad and membranous, into an impression occupying the posterior part of the upper end of the olecranon process of the ulna (Fig. 271, p. 351), and into the deep fascia of the forearm on either side of it. The long and outer heads join the borders of the tendon of

insertion, and the inner head is attached to its deep surface. A small thick-walled bursa separates the tendon of the triceps from the posterior ligament of the elbow-joint and the anterior part of the upper end of the olecranon process.

The long head of the triceps is concealed at first by the teres major and teres minor, and by the deltoid muscle. Along with the outer head it conceals the musculo-spiral nerve and superior profunda artery, and covers the inner head of the muscle. The inner is the deep head, and is only visible at the lateral borders of the muscle.

The **subanconeus** is a small muscle occasionally present, which consists of scattered fibres **arising** from the lower end of the humerus beneath the triceps, and **inserted** into the posterior ligament of the elbow-joint.

Nerve-Supply.

The following nerves supply the muscles of the arm :—

Muscles.	Nerves.	Origin.
Coraco-brachialis Biceps Brachialis anticus	Musculo-cutaneous	C. 7. C. 5. 6. C. 5. 6.
Brachialis anticus Triceps Outer head Middle and inner heads	Musculo-spiral	C. (5) 6. C. (6) 7. 8. C. 7. 8.

Actions.

(1) The chief action of these muscles (excepting the coraco-brachialis) is on the elbow-joint, producing along with other muscles flexion and extension. The flexor muscles are much more powerful than the extensors.

Table of Muscles acting on the Elbow-Joint.

Flexors.	Extensors.
Biceps	Triceps
Brachialis anticus	Anconeus
Brachio-radialis	Extensors of wrist and fingers (in supination)
Pronator radii teres	
Flexors of wrist and fingers	
Extensors of wrist (in pronation)	

(2) **The coraco-brachialis** muscle acts only on the shoulder-joint, assisting the biceps as an adductor and flexor of the humerus.

(3) **Subordinate** and **accessory movements** are performed by all the muscles of this group except the brachialis anticus. The **biceps** supinates the forearm, flexes the elbow, and with the aid of the **coraco-brachialis** adducts and flexes the humerus at the shoulder-joint. The **triceps** through its scapular head adducts and extends the humerus, besides extending the elbow-joint.

FASCIÆ AND MUSCLES OF THE FOREARM AND HAND.

FASCIÆ.

The **superficial fascia** in the forearm presents no exceptional features. On the dorsum of the hand it is loose and thin; in the palm it is generally well furnished with fat, forming pads for the protection of the vessels and nerves. It is closely adherent to the palmar fascia and to the skin, especially along the lines of flexure.

The **palmaris brevis** is a quadrilateral subcutaneous muscle occupying the inner side of the hand under the superficial fascia. It **arises** from the inner border of the thick central portion of the palmar fascia and from the front of the anterior annular ligament of the wrist, and is **inserted** into the skin of the inner border of the hand for a variable distance. It covers the ulnar artery and nerve, branches of which supply it. Its action is to wrinkle the skin of the inner border of the

hand, and by raising up the skin and superficial fascia, to deepen the hollow of the hand.

The **deep fascia** of the forearm and hand is continuous above with the deep fascia of the arm. At the upper part of the forearm it is strengthened by additional fibres around the elbow; in front by fibres from the semilunar fascia of the biceps, behind by the fascial insertions of the triceps, and laterally by fibres derived from the humeral condyles in relation to the common tendons of origin of the flexor and extensor muscles of the forearm. It closely invests and gives origin to these muscles. It is attached to the posterior border of the ulna in the whole length of the forearm, and affords increased attachment to the flexor and extensor carpi ulnaris and the flexor profundus digitorum muscles. Above the wrist the fascia is pierced anteriorly by the tendon of the palmaris longus, and by the ulnar artery and nerve. At the wrist it gains attachment to the bones of the forearm and carpus, is greatly strengthened by addition of transverse fibres, and constitutes **the annular ligaments.**

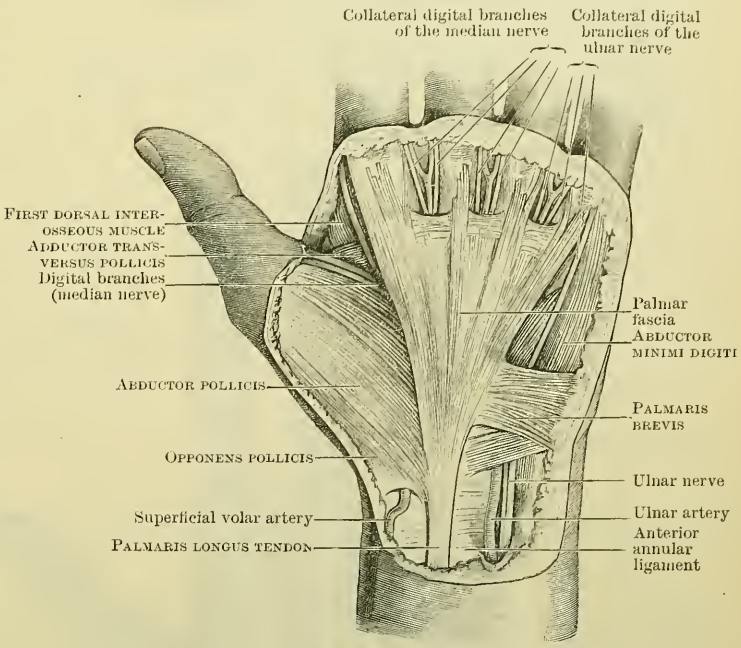


Fig. 259.—The Palm of the Hand (Superficial Dissection).

The **anterior annular ligament** of the wrist is a band about an inch and a half in depth, continuous above and below with the deep fascia of the forearm and the palm of the hand. It is attached to the scaphoid and trapezium externally: to the pisiform and unciform bones internally; and it forms a membranous arch binding down in the hollow of the carpus the flexor tendons of the fingers and the median nerve. It is divided into *two compartments*, the larger accommodating the tendons of the flexors of the digits and the median nerve, the smaller (placed externally) containing the tendon of the flexor carpi radialis. There are *three synovial membranes* in these compartments: one for the flexor carpi radialis tendon, and two others, which often communicate together, enveloping the tendon of the flexor longus pollicis and the flexor tendons of the fingers respectively. The surface of the ligament is crossed by the palmar branches of the median and ulnar nerves; by the tendon of the palmaris longus muscle, which is attached to its surface; and by the ulnar artery and nerve, which are again bridged over and protected by a band of fibrous tissue passing from the pisiform bone and the superficial fascia to the surface of the ligament. To the lower border of the ligament are attached the palmar fascia in the centre, and the superficial muscles of the thumb and the muscles of the little finger on each side.

The **posterior annular ligament** of the wrist is placed at a higher level than the previous ligament. It consists of an oblique band of fibres about an inch broad, continuous above and below with the deep fascia of the forearm and hand. It is attached externally to the outer side of the lower end of the radius, and internally to the lower end of the ulna (styloid process), the carpus, and the internal lateral ligament of the wrist. It is covered by veins, by the radial nerve,

and by the dorsal branch of the ulnar nerve. *Six compartments* are formed beneath it by the attachment of septal bands to the lower ends of the radius and ulna. Each compartment is provided with a *synovial membrane*, and they serve to transmit the extensor tendons of the wrist and fingers in the following order from without inwards:—

1. Extensor ossis metacarpi pollicis and extensor brevis pollicis.
2. Extensores carpi radiales, longior and brevior.
3. Extensor longus pollicis.
4. Extensor communis digitorum and extensor indicis.
5. Extensor minimi digiti.
6. Extensor carpi ulnaris.

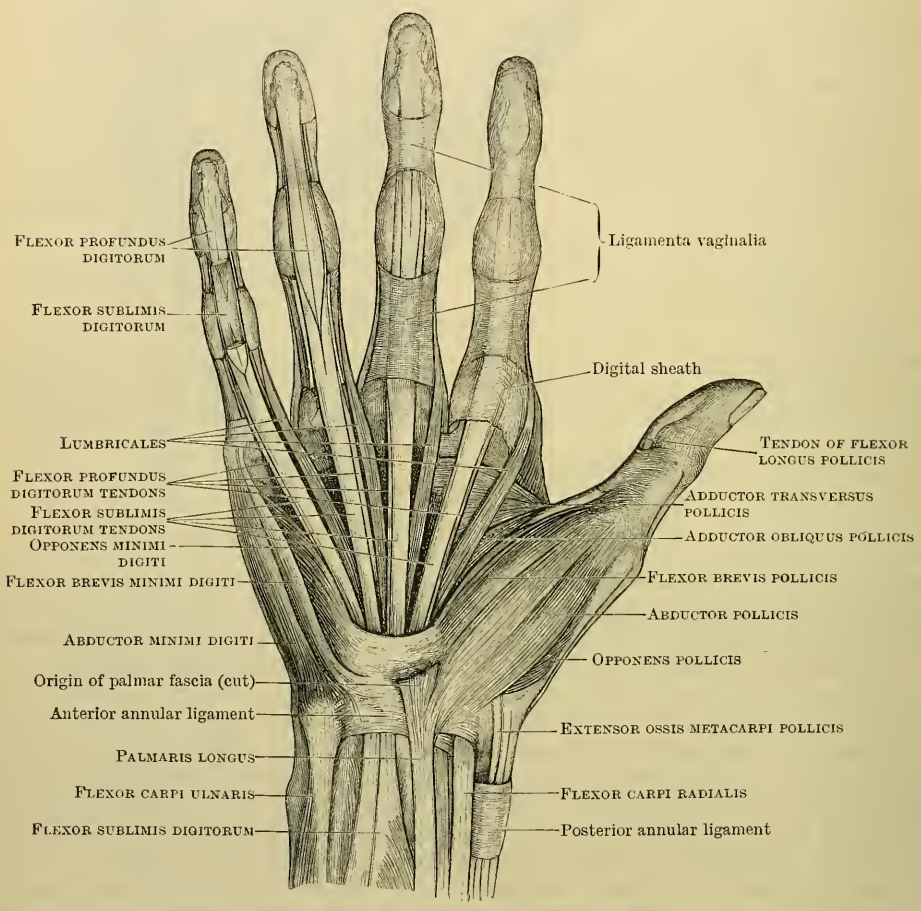


Fig. 260.—The Muscles and Tendons in the Palm of the Hand.

The thin deep fascia of the dorsum of the hand is lost over the expansions of the extensor tendons on the fingers. Between the metacarpal bones a strong layer of fascia covers and gives attachment to the interossei muscles.

The **palmar fascia** is of considerable importance. In the centre of the palm it forms a thick triangular membrane, the apex of which joins the lower edge of the anterior annular ligament, and receives the insertion of the tendon of the palmaris longus muscle. The fascia separates below into four slips, one for each finger, connected together by transverse fibres, forming beneath the webs of the fingers the **superficial transverse metacarpal ligament.** Beyond this each slip separates into two parts, to be connected to the sides of the metacarpo-phalangeal joints and the first phalanx of the inner four digits. In the cleft between the two halves of each slip the **digital sheath** is attached and extends downwards on to the finger. The lateral borders of this triangular central portion of the palmar fascia

are continuous with thin layers of deep fascia, which cover and envelop the muscles of the thenar and hypothenar eminences. The inner border gives origin to the *palmaris brevis muscle.*

The **digital sheaths** are tubular envelopes extending along the anterior aspect of the digits and enclosing the flexor tendons. Each consists of a fibrous sheath attached to the lateral borders of the phalanges and inter-phalangeal joints, and continuous above with the palmar fascia. Opposite each inter-phalangeal articulation the digital sheath is loose and thin; opposite the first two phalanges (the first only in the case of the thumb) it becomes extremely thick, and gives rise to the **ligamenta vaginalia**, which serve to keep the tendons closely applied to the bones during flexion of the fingers. Within each digital sheath are the flexor tendons, enveloped in a synovial membrane which not only envelops the tendon, but also lines the interior of the sheath. The synovial membranes of the digital sheaths extend a short distance upwards in the palm, and in some cases communicate with the large synovial membranes lining the flexor tendons beneath the annular ligament. There may be a separate distinct synovial membrane for each digit; but most commonly only the sheaths for the three middle digits have separate synovial membranes; those for the flexor longus pollicis and for the flexor tendons of the little finger communicate usually with the synovial membranes placed beneath the anterior annular ligament.

THE MUSCLES ON THE FRONT AND INNER ASPECT OF THE FOREARM.

The pronator and flexor muscles which lie on the front of the forearm occupy different levels, and are divisible into two main groups, **superficial** and **deep.**

Superficial Muscles.

The **superficial muscles** form the prominence on the front and inner side of the forearm, and all take origin in whole or part by means of a common tendon from the internal condyle of the humerus. The group comprises five muscles—pronator radii teres, flexor carpi radialis, palmaris longus, flexor carpi ulnaris, and flexor sublimis digitorum.

The **pronator radii teres** (m. pronator teres) is the most external and shortest muscle of this group. It has a double **origin**: (1) a *superficial head,* the main origin, partly fleshy, partly tendinous, from the lowest part of the internal supracondyloid ridge of the humerus and from the internal intermuscular septum, from the internal condyle of the humerus, from the fascia over it, and from an intermuscular septum between it and the flexor carpi radialis (Fig. 257, p. 335); (2) a *deep head,* a slender tendinous slip from the inner side of the coronoid process of the ulna, which joins the superficial origin of the muscle on its deep surface (Fig. 264, p. 343). The median nerve separates the two heads from one another. The muscle is directed downwards and outwards to be **inserted** by tendon into an oval impression on the middle of the outer surface of the shaft of the radius (Figs. 264, p. 343, and 271, p. 351). The fibres of the muscle are twisted on themselves, so that the highest humeral fibres form the lowest fibres of the tendon of insertion, and the lowest humeral fibres and those arising from the coronoid process are highest at the insertion of the muscle.

The muscle forms the inner boundary of the hollow of the elbow. It is superficially placed, except near its insertion, where it is covered by the brachio-radialis muscle and by the radial vessels and nerve. The flexor carpi radialis is on its inner side. The muscle conceals the ulnar and radial origins of the flexor sublimis digitorum, and the median nerve and ulnar artery, which are separated from one another by the deep head of origin.

The **flexor carpi radialis** muscle takes its **origin** from the common tendon from the internal condyle of the humerus, from the fascia over it, and from the intermuscular septa on either side. Its fleshy belly gives place to a strong round tendon in the lower half of the forearm, which, at the wrist, enters the hand in a

special compartment beneath the anterior annular ligament, and after occupying the groove on the trapezium, is **inserted** into the upper ends of the second and third metacarpal bones on their anterior surfaces. The chief tendon is that to the second metacarpal bone, which gives off a small slip on its inner side to be attached to the third metacarpal bone. Each is inserted about a quarter of an inch below the carpo-metacarpal joint (Fig. 267, p. 346).

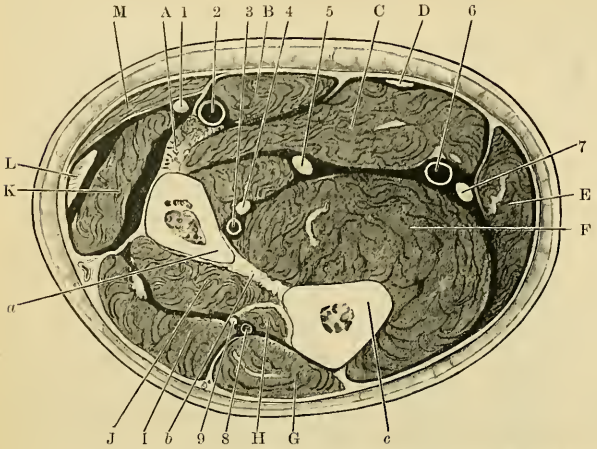


Fig. 261.—Section across the Forearm in the Middle Third.

A, Pronator radii teres (insertion); B, Flexor carpi radialis; C, Flexor sublimis digitorum; D, Palmaris longus; E, Flexor carpi ulnaris; F, Flexor profundus digitorum; G, Extensor carpi ulnaris; H, Extensor longus pollicis; I, Extensor communis digitorum and extensor minimi digiti; J, Extensor ossis metacarpi pollicis; K, Extensor carpi radialis brevior; L, Extensor carpi radialis longior; M, Brachio-radialis. *a*, Radius; *b*, Interosseous membrane; *c*, Ulna. 1, Radial nerve; 2, Radial Artery; 3, Anterior interosseous artery; 4, Anterior interosseous nerve (underneath flexor longus pollicis); 5, Median nerve; 6, Ulnar artery 7, Ulnar nerve; 8, Posterior interosseous artery; 9, Posterior interosseous nerve.

The chief tendon is that to the second metacarpal bone, which gives off a small slip on its inner side to be attached to the third metacarpal bone. Each is inserted about a quarter of an inch below the carpo-metacarpal joint (Fig. 267, p. 346).

The flexor carpi radialis is superficial except near its insertion. Its fleshy belly in the upper half of the forearm lies between the pronator radii teres and the palmaris longus, and conceals the flexor sublimis digitorum. Its tendon in the lower half of the forearm is subcutaneous, on the outer side of the palmaris longus tendon. It is an important guide to the radial vessels which are placed in the hollow external to it. Just above the wrist it crosses obliquely the tendon of the flexor longus pollicis. After passing beneath the anterior annular ligament the tendon is concealed by the origins of the short muscles of the thumb, and is crossed from within outwards by the tendon of the flexor longus pollicis. Besides the synovial bursa enveloping the tendon beneath the annular ligament, another is found beneath the tendons at their insertion.

The **palmaris longus** arises also from the common flexor tendon, from the internal condyle of the humerus, from the fascia over it, and from intermuscular septa on either side. It forms a short fusiform muscle, which ends in the middle of the forearm in a long flat tendon. This pierces the deep fascia above the wrist, and passing over the anterior annular ligament, is **inserted** (1) into the surface of the anterior annular ligament, and (2) into the apex of the thick central portion of the palmar fascia. A tendinous slip is frequently sent to the short muscles of the thumb and the fascia covering them.

The palmaris longus is the smallest muscle of the forearm. It is placed between the flexor carpi radialis and the flexor carpi ulnaris, and upon the flexor sublimis digitorum. In the lower third of the forearm its tendon is placed directly over the median nerve, along the outer border of the tendons of the flexor sublimis digitorum.

The palmaris longus is the most variable muscle in the body, and is often absent (10 per cent).

The **flexor carpi ulnaris** muscle has a double **origin**, from the humerus and from the ulna. (1) It arises from the common tendon attached to the inner condyle of the humerus, from the fascia over it, and from an intermuscular septum externally. (2) By means of the deep fascia of the forearm it obtains an attachment to the inner border of the olecranon process and the posterior border of the ulna in its upper three-fifths. The fleshy fibres join a tendon which lies on the anterior border of the muscle and is **inserted** into the pisiform bone. From the pisiform bone the fibres are continued in the form of two ligamentous bands (pisi-unciform and pisi-metacarpal) to be attached to the upper margin of the hook of the unciform bone, and the palmar surface of the upper end of the fifth metacarpal bone (Fig. 267, p. 346).

The muscle is superficially placed along the inner border of the forearm. It lies internal to the palmaris longus and flexor sublimis digitorum, and conceals the flexor profundus digitorum muscle. The ulnar nerve (which enters the forearm between the two heads of origin of the muscle) is concealed by it in its whole length. The ulnar artery lies under cover of the muscle in its lower two-thirds. The tendon of the muscle serves as a guide to the artery in the lower half of the forearm.

The **flexor sublimis digitorum** occupies a deeper plane than the four previous muscles. It has a threefold **origin**, from the humerus, radius, and ulna. (1) The chief or *humeral* origin is from the internal condyle of the humerus by the common tendon, from the internal lateral ligament of the elbow, and from adjacent inter-muscular septa. (2) The *ulnar* origin is by a slender fasciculus from the inner border of the coronoid process of the ulna, above and internal to the origin of the pronator radii teres (Fig. 264, p. 343). (3) The *radial* origin is from the oblique line and middle third of the anterior border of the radius by a thin fibro-muscular attachment (Fig. 264, p. 343).

The muscle divides in the lower third of the forearm into four parts, each provided with a separate tendon which passes beneath the anterior annular ligament, traverses the palm of the hand, and enters the corresponding digital sheath. Within the digital sheath each tendon is split into two parts by the tendon of the flexor profundus digitorum; after surrounding that tendon the two parts are partially re-united on its deep surface, and are **inserted**, after partial decussation, in two portions into the sides of the second phalanx.

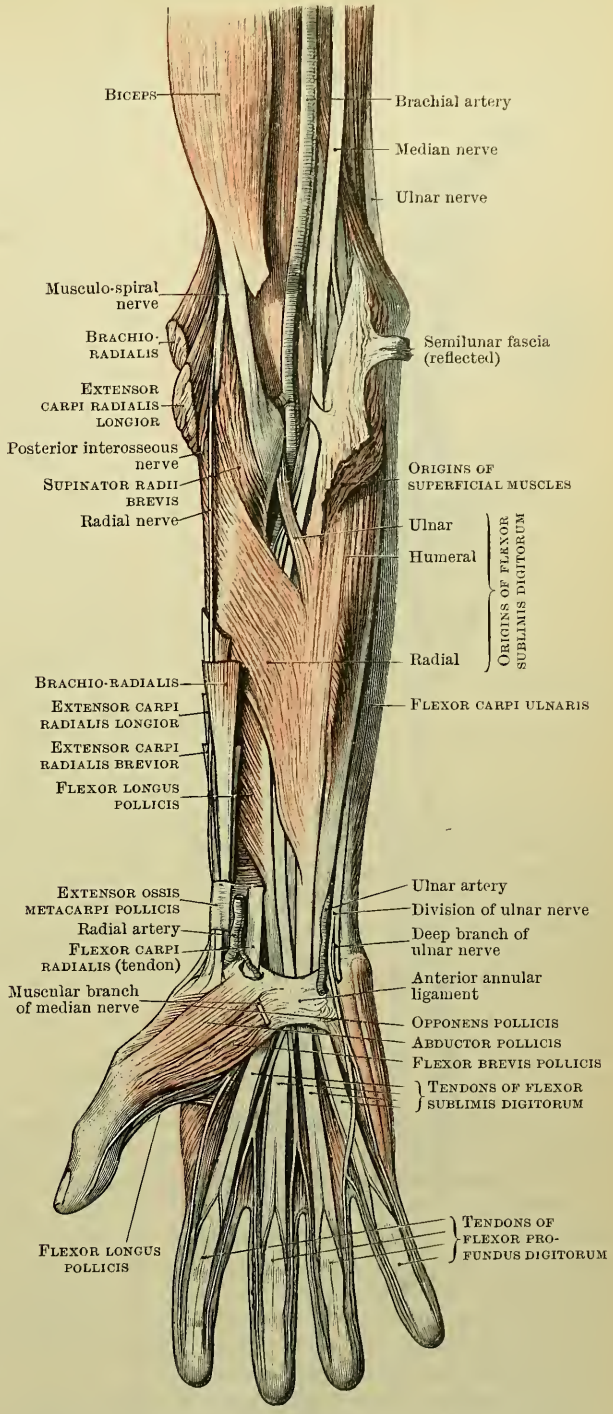


Fig. 262.—The Muscles and Nerves on the Front of the Forearm and Hand.

The pronator radii teres, flexor carpi radialis, and palmaris longus have been removed.

The **vincula accessoria tendinum** form additional insertions of the muscle. They consist of delicate bands of connective tissue enveloped in synovial membrane, and are known as the **ligamenta longa** and **brevia**. The ligamentum breve is a triangular band of fibres containing yellow elastic tissue (ligamentum subflavum), occupying the interval between the tendon and the digit for a short distance close to the insertion. It is attached to the front of the inter-phalangeal articulation and the head of the first phalanx. The ligamentum longum is a long narrow band extending from the back of the tendon to the upper part of the anterior surface of the first phalanx.

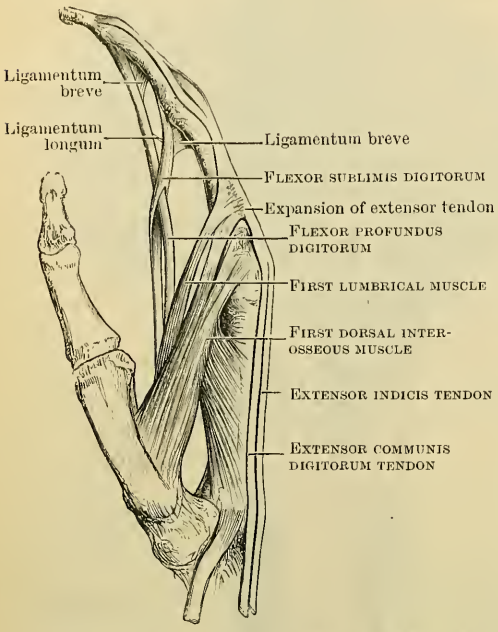


Fig. 263.—The Tendons attached to the Index Finger.

The flexor sublimis digitorum muscle is partially concealed in the forearm by the pronator radii teres, flexor carpi radialis, and palmaris longus muscles, and by the radial vessels and nerve. It conceals the flexor profundus digitorum and flexor longus pollicis muscles, the median nerve, and the ulnar artery. Its inner border is in contact with the flexor carpi ulnaris, and in the lower half of the forearm with the ulnar vessels and nerve. The median nerve emerges at its outer border above the wrist, and separates the muscle from the tendon of the flexor carpi radialis. At the wrist the four tendons are arranged in pairs, those for the middle and ring fingers in front, those for the fore and little fingers behind, and are enveloped in a synovial sheath (along with the tendons of the flexor profundus digitorum) beneath the anterior annular ligament. In the palm the tendons separate, and lying beneath the superficial palmar arch conceal the tendons of the deep flexor and the lumbrical muscles. Within the digital sheaths on the fingers the tendons at first conceal those of the deep flexor; after being pierced by them, they are in turn concealed by these tendons at their insertion.

Deep Muscles.

The **deep muscles** on the front of the forearm are three in number: flexor profundus digitorum, flexor longus pollicis, and pronator quadratus.

The **flexor profundus digitorum** is a large muscle **arising** from the ulna, the interosseous membrane, and the deep fascia of the forearm. Its ulnar origin is from the anterior and inner surfaces of the bone in its upper two-thirds, extending up so as to include the inner side of the olecranon process, and to embrace the insertion of the brachialis anticus into the coronoid process. It arises externally from the inner half of the interosseous membrane in its middle third (Figs. 264, p. 343, and 271, p. 351), and internally from the deep fascia of the forearm behind the origin of the flexor carpi ulnaris.

The muscle forms a broad thick tendon which passes beneath the anterior annular ligament, and divides in the palm into four tendons for **insertion** into the terminal phalanges of the fingers. The tendon associated with the forefinger is usually separate from the rest of the tendons in its whole length. Each tendon enters a digital sheath beneath the tendon of the flexor sublimis digitorum, which it pierces opposite the first phalanx, and is finally inserted into the base of the terminal phalanx. Like the tendons of the flexor sublimis, those of the deep

flexor are provided with vincula accessoria, viz. **ligamenta brevia** attached to the capsule of the second inter-phalangeal articulation, and **ligamenta longa**, which are in this case connected to the tendons of the subjacent flexor sublimis digitorum.

Lumbricales.—Four small cylindrical muscles are associated with the tendons of the flexor profundus digitorum in the palm of the hand. *The two outermost muscles* **arise** each by a single head from the radial sides of the tendons of the flexor profundus digitorum destined respectively for the fore and middle fingers. *The two innermost muscles* **arise**, each by two heads, from the adjacent sides of the second and third, and third and fourth tendons. From these origins the muscles are directed downwards to the radial side of each of the metacarpo-phalangeal joints, to be **inserted** into the capsules of these articulations, the outer border of the first phalanx, and chiefly into the outer side of the extensor tendon on the dorsum of the phalanx. The lumbricales vary considerably in number, and may be increased to six or diminished to two.

In the forearm the flexor profundus digitorum is concealed by the flexor sublimis digitorum and flexor carpi ulnaris muscles, and by the ulnar nerve and artery. Under the anterior annular ligament the muscle is placed beneath the tendons of the flexor sublimis digitorum, and is enveloped in the common bursal sac. In the palm the tendons, along with the lumbrical muscles, cover the deep palmar arch and the interossei muscles, and are concealed by the tendons of the flexor sublimis digitorum. On the finger each tendon is placed at first beneath, and afterwards pierces, the tendon of the flexor sublimis digitorum in its passage through the digital sheath. The lumbrical muscles passing downwards on the radial side of the deep flexor tendons lie beneath the digital vessels and nerves on their way to their insertion.

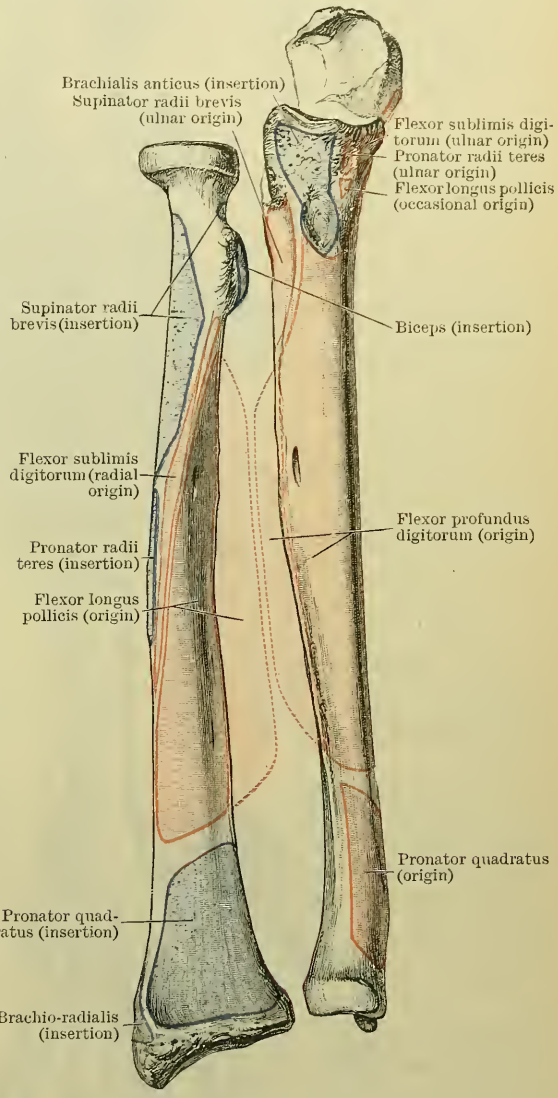


FIG. 264.—MUSCLE-ATTACHMENTS TO THE RADIUS AND ULNA (Anterior Aspects).

The **flexor longus pollicis arises** by fleshy fibres from the anterior surface of the shaft of the radius in its middle two-fourths, and from a corresponding portion of the interosseous membrane. It has an additional origin occasionally from the inner border of the coronoid process of the ulna (Fig. 264, p. 343). Its radial origin is limited above by the oblique line and the origin of the flexor sublimis digitorum, and below by the insertion of the pronator quadratus muscle. The muscle ends above the wrist in a tendon, which passes into the hand beneath the anterior annular ligament, enveloped in a special synovial sheath. In front of the carpus it crosses over the tendon of the flexor carpi radialis. In the palm the

tendon is directed downwards along the inner side of the thenar eminence, between the flexor brevis and adductor muscles of the thumb, to be **inserted** into the base of the terminal phalanx of the thumb on its anterior surface.

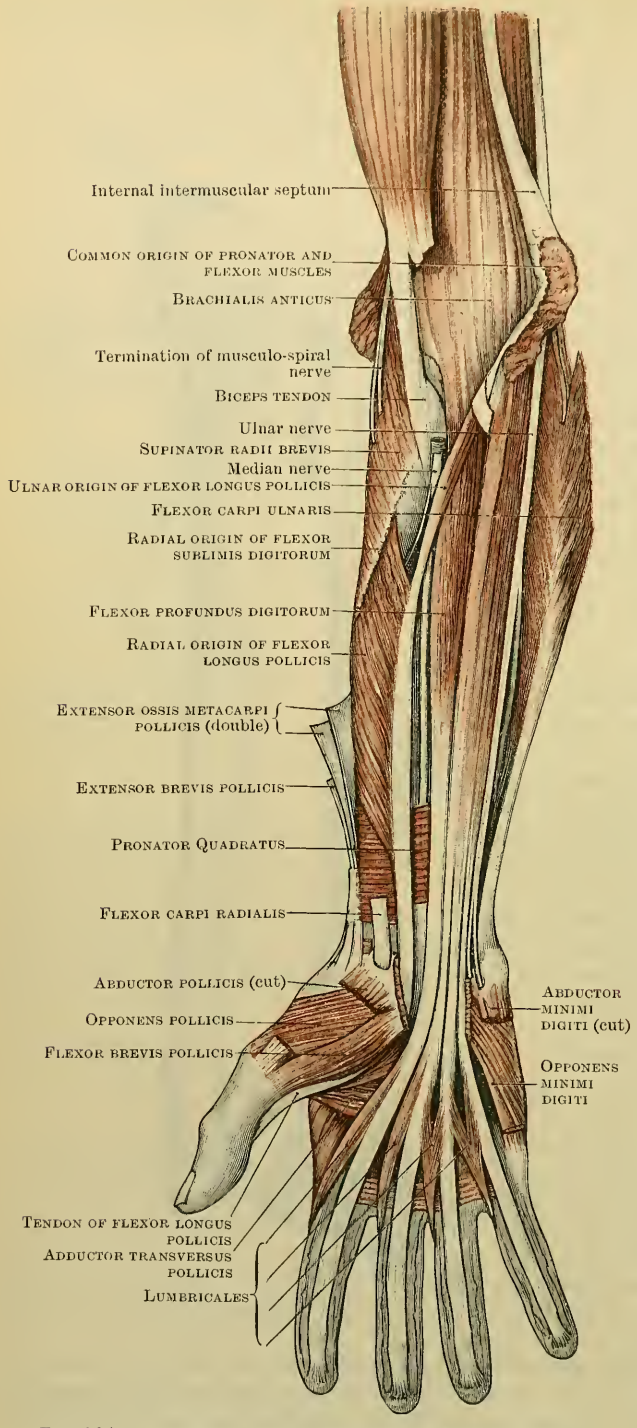


Fig. 265.—Deep Muscles on the Front of the Forearm and Hand.

In the forearm the muscle is deeply placed beneath the flexor sublimis digitorum and flexor carpi radialis muscles. The radial artery lies upon it, and the anterior interosseous artery and nerve intervene between it and the flexor profundus digitorum. It crosses over the insertion of the pronator quadratus near the wrist.

The **pronator quadratus** is a quadrilateral fleshy muscle, occupying the lower fourth of the forearm. It **arises** from the lower fourth of the anterior border and surface of the ulna and frequently from the adjoining part of the inner surface (Fig. 271, p. 351), and is directed transversely outwards to be **inserted** into the lower fourth of the anterior surface of the radius, and into the narrow triangular area on its inner side in front of the attachment of the interosseous membrane (Fig. 264, page 343).

The muscle is deeply placed beneath the flexor tendons, the radial and ulnar arteries, and the ulnar and median nerves. It conceals the lower part of the interosseous membrane, the radius and ulna, and the anterior interosseous artery and nerve, which pass behind its upper border. The pronator quadratus is subject to considerable variations. It may even be absent; or it may have an origin from radius or ulna, or from both bones, and an insertion into the carpus.

SHORT MUSCLES OF THE HAND.

Muscles of the Thumb.

The short muscles of the thumb are six in number, abductor, opponens, and flexor brevis (with its deep portion, **interosseus primus volaris**), and two adductor muscles, adductor obliquus, and adductor transversus pollicis.

The **abductor pollicis** (m. abductor pollicis brevis) **arises** by fleshy fibres from the tubercle of the scaphoid, the upper part of the outer surface of the ridge of the trapezium, the upper part of the anterior surface of the anterior annular ligament at its outer end, and from tendinous slips derived from the insertions of the palmaris

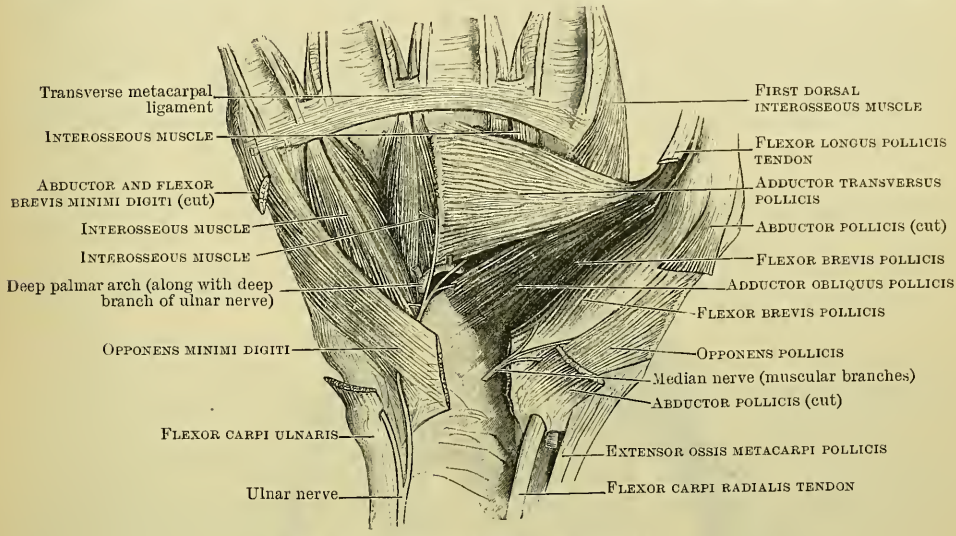


Fig. 266.—Short Muscles of the Hand.

longus and extensor ossis metacarpi pollicis muscles (Fig. 267, p. 346). Strap-like in form, it is **inserted** by a short tendon into the outer side of the first phalanx of the thumb at its upper end, and into the capsule of the metacarpo-phalangeal joint.

It is the most superficial muscle of the thenar eminence, and conceals partially the opponens and the superficial portion of the flexor brevis pollicis.

The **opponens pollicis arises** beneath the preceding muscle by fleshy and tendinous fibres from the lower and outer part of the anterior surface of the anterior annular ligament and from the outer surface of the ridge on the trapezium. Extending downwards and outwards, it is **inserted** into the whole length of the outer border and the radial half of the palmar surface of the first metacarpal bone (Fig. 267, p. 346). The muscle is superficial along the outer border of the abductor pollicis.

The **flexor brevis pollicis** consists of two parts. *a. The superficial part of the muscle* **arises** by fleshy and tendinous fibres from the outer half or two-thirds of the lower border of the anterior annular ligament, and sometimes from the ridge of the trapezium, and is **inserted** into the outer side of the base of the first phalanx of the thumb, a sesamoid bone being present in the tendon of insertion. This part of the muscle, partly concealed by the abductor pollicis, is superficial in the interval between that muscle and the tendon of the flexor longus pollicis.

b. The deep part of the muscle (interosseus primus volaris) **arises** from the ulnar side of the base of the first metacarpal bone, and is **inserted** into the inner side of the base of the first phalanx of the thumb along with the adductor obliquus pollicis. This little muscle is deeply situated in the first interosseous space, in the interval between the adductor obliquus pollicis and the first dorsal interosseous muscle. It may be regarded as homologous with the palmar interossei muscles, with which it is in series.

The **adductor obliquus pollicis arises** by fleshy fibres from the anterior surfaces of the trapezium, trapezoid, and os magnum, from the sheath of the tendon of the flexor carpi radialis, from the basis of the second, third, and fourth metacarpal bones, and from the palmar ligaments connecting these bones together (Fig. 267, p. 346). It is **inserted** by a tendon, in which a sesamoid bone is developed, into the inner side of the base of the first phalanx of the thumb. At its outer border a slender slip separates from the rest of the muscle, and passing obliquely beneath the tendon of the flexor longus pollicis, is inserted into the outer side of the base of the first phalanx along with the superficial part of the flexor brevis pollicis.

The adductor obliquus pollicis lies on the ulnar side of the tendon of the flexor longus pollicis, internal to the thenar eminence. It is covered by the flexor tendons of the thumb and fingers, and conceals the radial artery and the deep part of the flexor brevis pollicis. At its inner border the radial artery (deep palmar arch) appears between it and the adductor transversus pollicis.

The **adductor transversus pollicis arises** by fleshy fibres from the median ridge

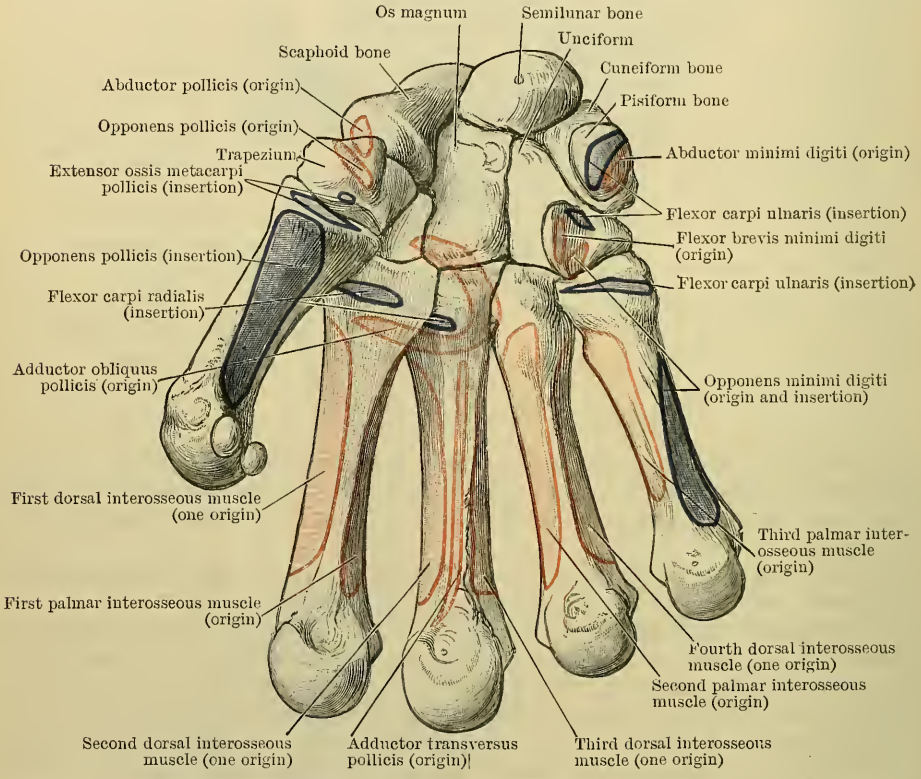


FIG. 267.—MUSCLE-ATTACHMENTS TO THE PALMAR ASPECT OF THE CARPUS AND METACARPUS.

on the front of the shaft of the third metacarpal bone, in its lower two-thirds (Fig. 267, p. 346), and from the fascia covering the interosseous muscles in the second and third spaces. Triangular in form, it is directed outwards, to be **inserted** by tendon into the inner side of the base of the first phalanx of the thumb along with the adductor obliquus. Lying deeply in the palm beneath the flexor tendons, this muscle conceals the interossei muscles of the first two spaces and the radialis indicis and princeps pollicis arteries. Its upper border is separated from the adductor obliquus pollicis by the radial artery (deep palmar arch).

MUSCLES OF THE LITTLE FINGER.

The short muscles of the little finger are three in number: abductor, opponens, and flexor brevis minimi digiti.

The **abductor minimi digiti** (m. abductor digiti quinti) arises from the front and inner side of the pisiform bone and from the tendon of the flexor carpi ulnaris and its ligamentous continuations (Fig. 267, p. 346), and is inserted by tendon into the inner side of the base of the first phalanx of the little finger. It lies superficially upon the opponens and flexor brevis minimi digiti.

The **opponens minimi digiti** (m. opponens digiti quinti) arises by tendinous fibres from the lower part of the anterior surface and from the lower border of the anterior annular ligament at its inner end, and from the lower border and inner side of the hook of the unciform bone, and is inserted into the inner margin and ulnar half of the palmar surface of the fifth metacarpal bone in its lower three-fourths (Fig. 267, p. 346).

It is concealed by the previous muscle, and may be pierced near its origin for the passage of the deep branches of the ulnar artery and nerve.

The **flexor brevis minimi digiti** (m. flexor digiti quinti brevis) arises by tendinous fibres from the inner part of the anterior surface of the anterior annular ligament and from the inner side of the hook of the unciform bone (Fig. 267, p. 346), and is inserted along with the abductor into the inner side of the first phalanx of the little finger.

This muscle is placed external to the opponens and abductor, and is separated from the latter by the deep branches of the ulnar artery and nerve. It may be reduced in size, absent altogether, or incorporated with either the opponens or abductor minimi digiti.

The Interosseous Muscles.

The interosseous muscles of the hand are arranged in two sets, palmar and dorsal.

The **palmar interossei** (m. interossei volares) are three in number, occupying the three inner interosseous spaces. Each arises by a single head; the *first* from the ulnar side of the shaft of the second metacarpal bone; the *second* and *third* from the radial sides of the shafts of the fourth and fifth metacarpal bones respectively (Fig. 267, p. 346). Each ends in a tendon which is directed downwards behind the deep transverse metacarpal ligament, to be inserted into the dorsal expansion of the extensor tendon, the capsule of the metacarpo-phalangeal articulation, and the side of the first phalanx of the finger; the *first* is inserted into the ulnar side of the second finger; the *second* and *third* into the radial sides of the fourth and fifth fingers. The deep part of the flexor brevis pollicis (interosseus primus volaris) is to be regarded as the homologous muscle of the first interosseous space.

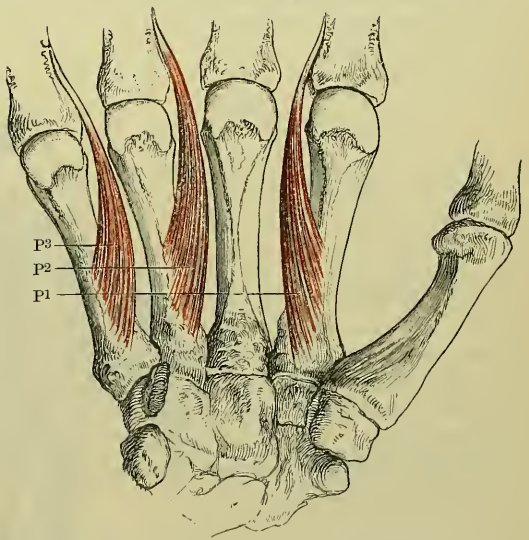


Fig. 268.—The Palmar Interosseous Muscles.

P^1, first; P^2, second; and P^3, third palmar interosseous muscles.

The **dorsal interossei** are four in number. Each arises by two heads from the sides of the metacarpal bones bounding each interosseous space (Figs. 267, p. 346, and 269, p. 348). Each forms a fleshy mass, ending in a membranous tendon, which, passing downwards behind the deep transverse metacarpal ligament, is inserted exactly like the palmar muscles into the dorsal aspect of each of the four fingers. The insertion of the *first* dorsal interosseous muscle is into the radial side of the index finger; the *second* muscle is attached to the radial side of the

middle finger; the *third* muscle to the ulnar side of the same finger; and the *fourth* muscle to the ulnar side of the ring finger.

These muscles fill up the interosseous spaces; the dorsal interossei are visible

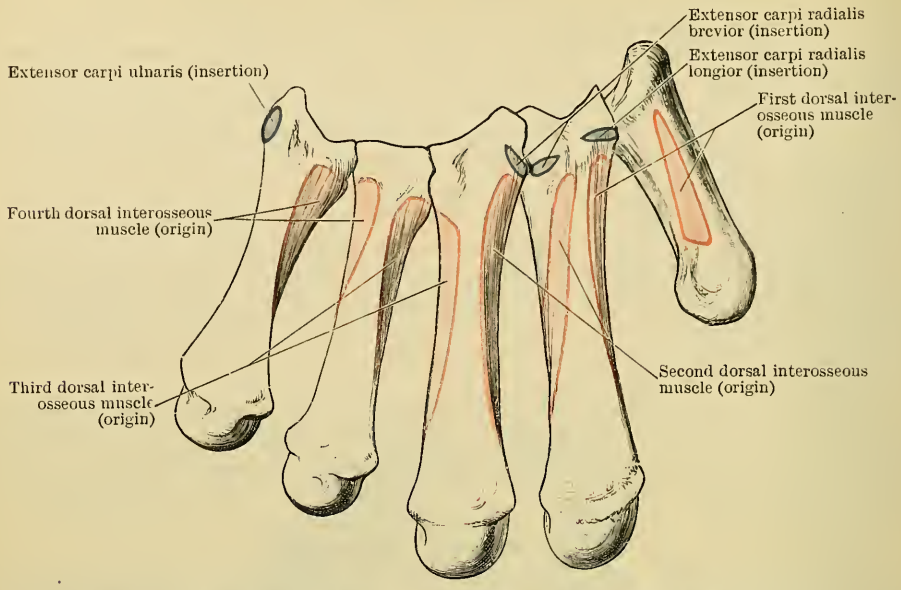


FIG. 269.—MUSCLE-ATTACHMENTS TO THE DORSAL ASPECT OF THE METACARPUS.

on the back of the hand when the extensor tendons are removed; in the palm the muscles are concealed by the flexor tendons and the muscles of the thumb and little finger, and are crossed by the deep palmar arch and the deep branch of the

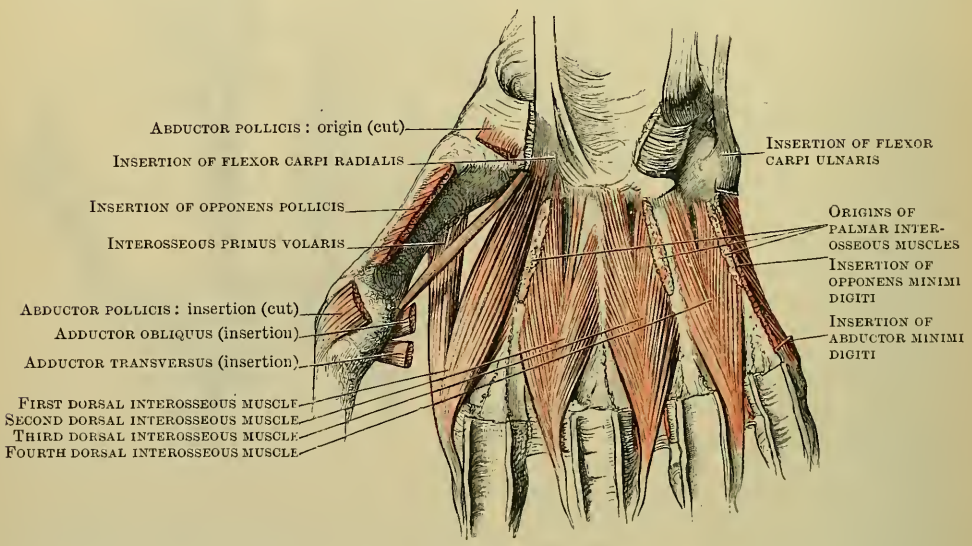


FIG. 270.—DORSAL INTEROSSEOUS MUSCLES OF THE HAND (seen from the Palmar Aspect).

ulnar nerve. Between the two heads of the first dorsal muscle the radial artery enters the palm, and the perforating arteries pass between the heads of the other dorsal muscles.

The interossei muscles of the hand in some cases have a disposition similar to that of the corresponding muscles of the foot.

THE MUSCLES ON THE BACK OF THE FOREARM.

The group of muscles occupying the outer side of the elbow and the back of the forearm and hand include the supinator muscles of the forearm and the extensors of the wrist and digits. They are divisible into a **superficial** and a **deep layer.**

Superficial Muscles.

The **superficial layer** comprises seven muscles, viz. from without inwards, the brachio-radialis, the two radial extensors of the carpus, the extensor communis digitorum and extensor minimi digiti, the extensor capri ulnaris, and the anconeus.

The **brachio-radialis** (supinator radii longus) **arises** by fleshy fibres from the anterior aspect of the upper two-thirds of the external supra condyloid ridge of the humerus, and from the front of the external intermuscular septum (Fig. 257, p. 335). Occupying the outer side of the hollow of the elbow, the muscle descends along the outer border of the forearm, and ends about the middle in a narrow flat tendon which is **inserted** under cover of the tendons of the extensor ossis metacarpi pollicis and extensor brevis pollicis, by a transverse linear attachment, into the upper limit of the groove for the above-named muscles on the outer side of the lower extremity of the radius. Some of its fibres gain an attachment to the ridge in front of the groove, and others spread over the surface of the groove for a variable distance (Figs. 271, p. 351, and 264, p. 343).

The muscle is superficial in its whole length. Near its origin it is separated from the brachialis anticus by the musculo-spiral nerve. It forms the outer boundary of the hollow of the elbow, and conceals the radial extensors of the carpus, and, in the upper two-thirds of the forearm, the radial artery and nerve.

The **extensor carpi radialis longior** (m. ext. carp. rad. longus) **arises** by fleshy fibres from the lower third of the external supracondyloid ridge of the humerus on its anterior aspect, from the front of the external intermuscular septum, and from the common tendon of origin of succeeding muscles, which is attached to an impression on the antero-external surface of the external condyle (Figs. 257, and 258, p. 335). It ends in a tendon in the lower half of the forearm, which passes beneath the posterior annular ligament, to be **inserted** into the back of the base of the second metacarpal bone on its radial side (Fig. 269, p. 348).

The upper part of the muscle is concealed by the brachio-radialis, and the lower part is crossed by the extensors of the thumb. It covers the supinator radii brevis and extensor carpi radialis brevior above, and the back of the radius and the carpus below.

The **extensor carpi radialis brevior** (m. ext. carp. rad. brevis) **arises** from the common tendon, from the external lateral ligament of the elbow, from the fascia over it, and from intermuscular septa on each side. It passes down the back of the forearm and under the posterior annular ligament in close relation to the previous muscle, to be **inserted** by a tendon into the back of the base of the third metacarpal bone below the styloid process on its radial side. It usually has an additional insertion into the back of the base of the second metacarpal bone (Fig. 269, p. 348). A bursa is placed beneath the two radial extensor tendons close to their insertion.

Partially concealed by the extensor carpi radialis longior and the extensor muscles of the thumb, and having the extensor communis digitorum on its inner side, the muscle covers the supinator brevis, the lower part of the radius, and the back of the carpus.

The **extensor communis digitorum** **arises** from the common tendon, from the external condyle, from the fascia over it, and from intermuscular septa on each side. Extending down the back of the forearm it ends above the wrist in four tendons, of which the outermost often has a separate fleshy belly. After passing beneath the posterior annular ligament in a compartment along with the extensor indicis, the tendons separate on the back of the hand, where the three innermost tendons are joined together by two obliquely-placed bands. One passes downwards and outwards, and connects together the third and second tendons; the other is a broader

and shorter band, which passes also downwards and outwards, and joins the fourth to the third tendon. In some cases (Fig. 257) a third band is present, which passes downwards and inwards from the first to the second tendon; and frequently the tendon for the little finger is joined to the tendon for the ring finger, and separates from it only a short distance above the lower end of the metacarpal bone.

The tendons are **inserted** in the following manner: On the finger each tendon spreads out so as to form a membranous expansion over the knuckle and on the back of the first phalanx. The border of the tendon is indefinite over the metacarpo-phalangeal articulation, of which it forms the posterior ligament. On the back of the first phalanx the tendon receives laterally the insertions of the interossei and lumbrical muscles. At the lower end of the first phalanx the tendon splits into ill-defined median and lateral slips, proceeding over the back of the first inter-phalangeal articulation, of which they form the posterior ligament. The median slip is inserted into the back of the base of the second phalanx, while the two lateral pieces become united to form a membranous tendon on the back of the second phalanx, which, after passing over the second inter-phalangeal articulation, is inserted into the base of the terminal phalanx.

The extensor communis digitorum is superficial in its whole length, and lies in the upper part of the forearm between the radial extensors of the carpus externally and the extensor minimi digiti internally. It conceals the supinator brevis and other deep muscles of the forearm, as well as the posterior interosseous vessels and nerves. The extensors of the thumb become superficial along its outer border in the lower third of the forearm.

The **extensor minimi digiti** (m. extensor digiti quinti proprius) has an **origin** similar to and closely connected with that of the preceding muscle, from the common tendon, the fascia over it, and lateral intermuscular septa. Passing down the back of the forearm as a narrow fleshy slip, between the extensor communis digitorum and the extensor carpi ulnaris, it ends in a tendon which occupies a groove between the radius and ulna in a special compartment of the posterior annular ligament. On the back of the hand the tendon, usually split into two parts, lies internal to the tendons of the extensor communis digitorum, and is finally **inserted** into the expansion of the extensor tendon on the dorsum of the first phalanx of the little finger.

The **extensor carpi ulnaris** has a double **origin**: (1) from the common tendon from the external condyle of the humerus, from the fascia over it, and from the intermuscular septa; and (2) through the medium of the deep fascia, from the posterior border of the ulna in its middle two-fourths. The muscle ends in a tendon in the lower third of the forearm, which occupies a groove on the back of the ulna in a special compartment of the posterior annular ligament, and is **inserted** into the ulnar side of the base of the fifth metacarpal bone (Fig. 269, p. 348).

The muscle is superficially placed between the extensor minimi digiti and the anconeus, external to the posterior border of the ulna. It conceals the supinator radii brevis and the posterior interosseous vessels and nerve above, and in the lower two-thirds of the forearm it lies upon the posterior surface of the ulna.

The **anconeus** is a small triangular muscle **arising** by a separate tendon from the lower part of the back of the external condyle of the humerus (Fig. 258, p. 335), and from the posterior ligament of the elbow-joint. Spreading out over the ulna, it is **inserted** by fleshy fibres into a triangular surface on the outer side of the olecranon process and back of the ulna, as low down as the oblique line (Fig. 271, p. 351). It is also inserted into the fascia which covers it.

It is covered by the thickened fascia of the forearm giving insertion to the triceps muscle. It conceals the back of the elbow-joint and part of the origin of the supinator brevis muscle.

The **epitrochleo-anconeus** is an occasional small muscle **arising** from the back of the internal condyle of the humerus, and **inserted** into the inner side of the olecranon process. It covers the ulnar nerve in its passage to the forearm.

Deep Muscles.

The **deep muscles** on the back of the forearm comprise five muscles, of which

one, the supinator radii brevis, extends between the ulna and radius; the others are extensors of the thumb and forefinger: the extensor ossis metacarpi pollicis, extensor brevis and extensor longus pollicis, and extensor indicis.

The **supinator radii brevis** (m. supinator) muscle has a complex **origin**. It **arises** by fleshy and tendinous fibres: (1) from the external condyle of the humerus; (2) from the external lateral and orbicular ligaments of the elbow-joint; (3) from the triangular surface on the shaft of the ulna just below the lesser sigmoid cavity; and (4) from the fascia over it. From this origin the muscle spreads outwards and downwards, enveloping the upper part of the radius, and is **inserted** into the anterior and outer surfaces of the bone, as far forwards as the bicipital tubercle, as far upwards as the neck, and as far downwards as the oblique line and the insertion of the pronator radii teres. The insertion of the muscle in some cases encroaches for a variable distance on to the posterior surface of the shaft of the radius above the origin of the extensor ossis metacarpi pollicis; but the neck and the inner half of the posterior surface of the shaft are left without muscular attachment (Figs. 271, p. 351, and 264, p. 343).

The supinator brevis is deeply placed, and is uncovered only anteriorly in the hollow of the elbow. It is covered by all the superficial muscles on the back of the forearm. It conceals the back of the elbow-joint and the upper part of the radius. At its lower border is the extensor ossis metacarpi pollicis, separated from it by the posterior interosseous artery. The muscle is divisible into *superficial* and *deep parts* with humeral and ulnar origins, between which the posterior interosseous nerve passes in its course to the back of the forearm.

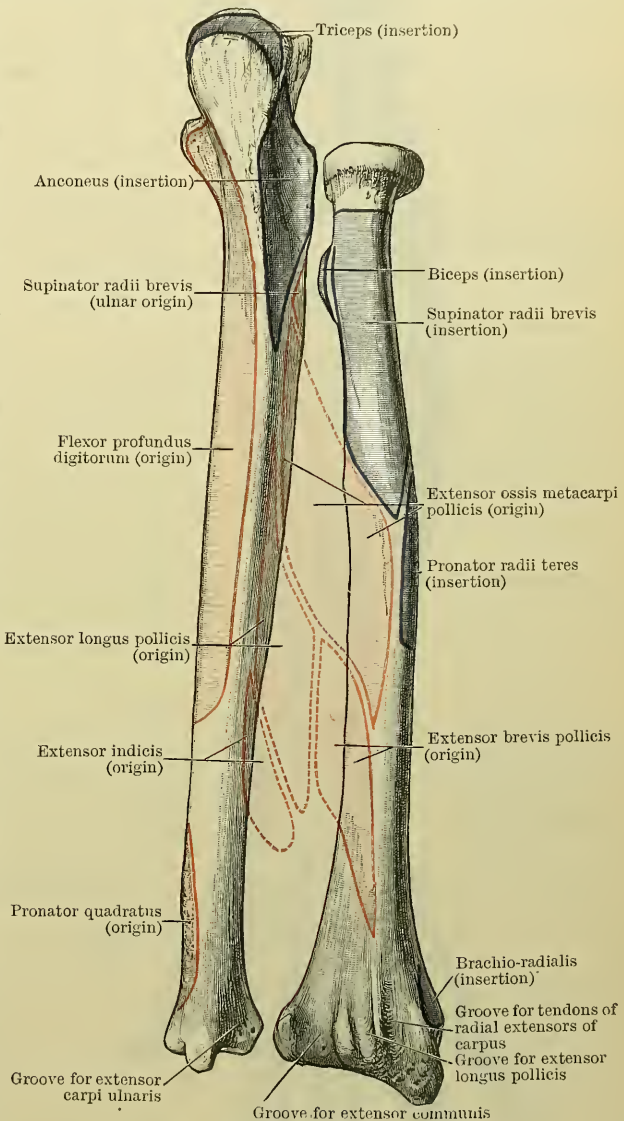


FIG. 271.—MUSCLE-ATTACHMENTS TO THE RADIUS AND ULNA (Posterior Aspects).

The **extensor ossis metacarpi pollicis** (m. abductor pollicis longus) **arises** by fleshy fibres below the supinator brevis from the posterior or extensor surfaces of the shafts of the radius and ulna; from the uppermost of the narrow impressions on the outer half of the posterior surface of the ulna; from the middle third of the posterior surface of the radius; and from the intervening portion of the interosseous membrane (Fig. 271, p. 351). Becoming superficial in the lower part of the forearm along with the extensor brevis pollicis, its tendon passes with that

muscle beneath the posterior annular ligament, to be **inserted** into the outer side of the base of the first metacarpal bone (Fig. 267, p. 346). From the tendon close to its insertion a tendinous slip passes to the abductor pollicis and the fascia over the thenar eminence, and another is frequently attached to the trapezium.

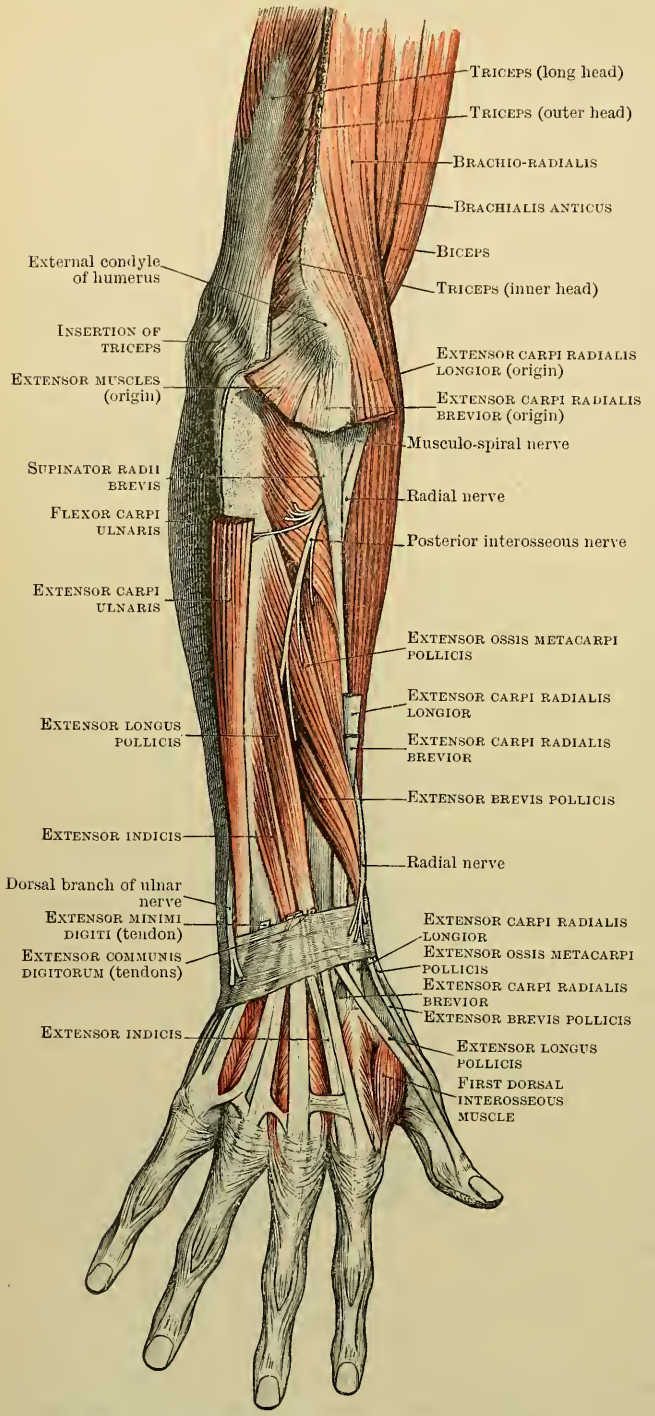


Fig. 272.—The Muscles of the Back of the Forearm (the superficial muscles being reflected).

At its origin the muscle is deeply placed beneath the superficial extensor muscles and the posterior interosseous vessels and nerve. Above is the supinator brevis; below and internally, the long and short extensors of the thumb. In the lower third of the forearm it becomes superficial along with the extensor brevis pollicis, between the extensor communis digitorum and the radial extensors of the carpus. It covers the last-named muscles in its further course in the forearm, and at the outer side of the carpus it crosses the radial artery.

The **extensor brevis pollicis** (extensor primi internodii pollicis), an essentially human muscle, is a specialised portion of the previous muscle. It **arises** from a rhomboid impression on the posterior surface of the radius, extending from the middle of the bone to within an inch and a half of the lower end, and from the interosseous membrane, below the extensor ossis metacarpi pollicis (Fig. 271, page 351). It is closely adherent to that muscle, and accompanies it beneath the posterior annular ligament and over the radial artery to the thumb. Its tendon is then continued along the back of the first metacarpal bone, and the metacarpophalangeal articulation, to be **inserted** into the back of the base of the first phalanx of the thumb. Before reaching its insertion the tendon helps to form the capsule

of the metacarpo-phalangeal joint. In the forearm the muscle is deeply placed beneath the superficial extensors, and is separated from the extensor longus pollicis by the posterior interosseous nerve.

The **extensor longus pollicis** (extensor secundi internodii pollicis) **arises** from the intermediate impression occupying the outer part of the posterior or extensor surface of the ulna in its middle third, and from the interosseous membrane, below the extensor ossis metacarpi pollicis (Fig. 271, p. 351). Its tendon grooves the back of the radius, and occupies a special compartment beneath the posterior annular ligament. Extending obliquely across the back of the hand, it is **inserted** into the dorsal surface of the base of the second phalanx of the thumb.

The muscle is deeply placed beneath the superficial extensors of the forearm, and lies between the extensor brevis pollicis and the extensor indicis. It separates the posterior interosseous artery from the nerve, the latter passing beneath it. On the back of the hand the tendon crosses the radial artery, and helps to form the capsule of the first metacarpo-phalangeal articulation.

At the wrist the tendons of the muscles of the thumb, the extensor ossis metacarpi pollicis and extensor brevis pollicis externally, and the extensor longus pollicis internally, bound a hollow (the "anatomical snuff-box") best seen in extension and abduction of the thumb, which corresponds to the position of the radial artery as it winds round the wrist to reach the palm of the hand.

The **extensor indicis** (m. extensor indicis proprius) **arises** by fleshy fibres below the extensor longus pollicis from the lowest impression on the back of the ulna, extending down from the middle of the shaft to within two inches of its lower end, and sometimes also from the interosseous membrane (Fig. 271, p. 351). Its tendon passes through a compartment of the posterior annular ligament along with the tendons of the extensor communis digitorum, and is **inserted** into the forefinger joining the membranous expansion of the tendon of the extensor communis digitorum on the dorsum of the first phalanx.

Lying deeply in the forearm, the muscle is placed internal to the extensor longus pollicis, and covers the posterior interosseous nerve. On the back of the hand its tendon lies on the inner side of the tendon of the common extensor destined for the forefinger.

Nerve-Supply.

Four nerves are engaged in supplying the muscles of the forearm and hand—the median and ulnar on the front, the musculo-spiral and posterior interosseous nerves on the back of the limb.

Muscles.	Nerves.	Origin.
A. Anterior Muscles of the Forearm.		
Pronator radii teres Flexor carpi radialis Palmaris longus Flexor sublimis digitorum	Median	C. 6.
Flexor carpi ulnaris	Ulnar	C. 8. T. 1.
Flexor profundus digitorum	Ulnar and Anterior interosseous (median)	C. 8. T. 1. C. 7. 8. T. 1.
Flexor longus pollicus Pronator quadratus	Anterior interosseous	C. 7. 8. T. 1.
B. Muscles of the Hand.		
Abductor pollicis Opponens pollicis Flexor brevis pollicis (superficial)	Median	C. 6. 7.
Flexor brevis pollicis (deep) Adductor obliquus pollicis Adductor transversus pollicis	Ulnar	C. 8. (T. 1).
Lumbricales 1st and 2nd	Median	C. 6. 7.
Lumbricales 3rd and 4th Interossei Flexor brevis minimi digiti Opponens minimi digiti Abductor minimi digiti	Ulnar	C. 8. (T. 1).

Muscles.	Nerves.	Origin.
C. **Posterior Muscles of the Forearm.**		
Brachio-radialis Extensor carpi radialis longior	Musculo-spiral	C. 5. 6. C. 6. 7.
Extensor carpi radialis brevior		C. 6. 7.
Extensor communis digitorum Extensor minimi digiti Extensor carpi ulnaris	Posterior interosseous (musculo-spiral)	C. 6. 7. 8.
Anconeus	Musculo-spiral	C. 7. 8.
Supinator radii brevis		C. 6.
Extensor ossis metacarpi pollicis Extensor brevis pollicis Extensor longus pollicis Extensor indicis	Posterior interosseous	C. 6. 7. 8.

Action of the Muscles of the Forearm and Hand.

The muscles of the forearm and hand are concerned in the movements of the elbow, wrist, and fingers.

In the majority of cases the muscles act upon more than one joint.

1. Action on the Elbow-Joint.—It has been shown already that flexion and extension of the elbow are assisted by certain of these muscles. The **flexor muscles** are the pronator radii teres, and the flexor muscles of the wrist and fingers. In the position of pronation, the movement of flexion is aided by the brachio-radialis and extensors of the wrist and fingers. The **extensors** are the supinator brevis and anconeus, and the extensor muscles of the wrist and fingers.

2. Pronation and supination of the hand are performed by special muscles, aided by muscles which act also upon other joints. The brachio-radialis assists in flexion and pronation on the one hand, and in extension and supination on the other hand. In the supine position it assists pronation, and in the prone position it assists supination, in each case bringing the hand into the position intermediate between pronation and supination.

Pronation.	Supination.
Pronator radii teres	Supinator radii brevis
Pronator quadratus	Biceps
Brachio-radialis	Brachio-radialis
Flexor carpi radialis	Extensors of thumb and fingers
Weight of the limb	Weight of the limb

3. Action on the Wrist-Joint.—The movements at the wrist-joint are flexion and extension, abduction and adduction. Flexion and adduction are much more extensive movements than extension and abduction, on account of the form of the wrist-joint. The following muscles produce these movements :—

Flexion.	Extension.	Adduction.	Abduction.
Flexor carpi radialis Palmaris longus Flexor carpi ulnaris Long flexors of thumb and fingers	Extensors of the wrist Extensors of thumb and fingers	Flexor carpi ulnaris Extensor carpi ulnaris	Flexor carpi radialis Extensors of wrist Extensors of thumb

4. Movements of the Fingers.—Two separate series of movements occur in relation to the articulations of the fingers: flexion and extension (at the metacarpo-phalangeal and inter-phalangeal joints), and abduction and adduction (only at the metacarpo-phalangeal joints). The movements and the muscles concerned are given in the following tables :—

Flexion.	Extension.
Flexor sublimis digitorum	Extensor communis digitorum
Flexor profundus digitorum	Extensor indicis
Lumbricales (*acting on the metacarpo-* Interossei *phalangeal articulations*)	Extensor minimi digiti
Flexor brevis minimi digiti	Lumbricales (*acting on the inter-phal-* Interossei *angeal articulations*)

Abduction.	Adduction.
Lumbricales Flexor brevis and Opponens minimi digiti (from the inner side of the hand) Dorsal interossei (from the middle line of the middle finger)	Palmar interossei (to the middle line of the middle finger)

Flexion is more powerful and complete than extension of the fingers. The flexor profundus digitorum alone acts on the terminal phalanges; the flexor sublimis and flexor profundus together flex the proximal inter-phalangeal joint; and flexion of the metacarpo-phalangeal articulation is effected by these muscles, assisted by the interossei, lumbricales, and flexor brevis minimi digiti. Extension of the phalanges is effected by the united action of the extensors of the digits, the interossei and lumbricales; extension of the fingers at the metacarpo-phalangeal joints is produced solely by the long extensor muscles. *Separate extension of the index finger* only is possible; the three inner fingers can only be flexed and extended together, on account of the connecting bands joining the extensor tendons together on the back of the hand.

5. Movements of the Thumb.—The movements of which the thumb is capable are flexion and extension (occurring at the carpo-metacarpal, metacarpo-phalangeal, and inter-phalangeal joints); abduction and adduction, together with circumduction (occurring at the carpo-metacarpal joint).

The muscles and their respective actions are given in the following table:—

Flexion.	Extension.
Opponens pollicis (carpo-metacarpal joint) Flexor brevis, Adductors, Abductor (carpo-metacarpal and metacarpo-phalangeal joint) Flexor longus pollicis (all joints)	Extensor ossis metacarpi pollicis (carpo-metacarpal joint) Extensor brevis pollicis (carpo-metacarpal and metacarpo-phalangeal joint) Extensor longus pollicis (all joints)
Adduction.	**Abduction.**
Adductors of the thumb Flexor brevis, Opponens pollicis First dorsal interosseous	Abductor pollicis Extensors of the thumb
Circumduction—a combination of the above muscles.	

The characteristic features of the movements of the upper limb are their range and refinement. The hand, in addition to its intrinsic powers, can be moved through a wide range and in several planes by the muscles acting on the wrist and radio-ulnar joints; this range is increased by the fore and aft movements at the elbow-joint, and the extensive movements of which the shoulder and clavicular joints are capable. The result is that the hand can be brought into a position to cover and guard any portion of the body. The precision and refinement of movement is made possible by the co-ordinate movements of the various muscles acting upon the several joints, so that actions can be performed (as raising the food to the mouth) in which all the articulations of the limb are brought into play; while others (such as writing) are possible by movements at the joints of the wrist and fingers along with fixation of the elbow-joint.

THE LOWER LIMB.

FASCIÆ AND MUSCLES OF THE THIGH AND BUTTOCK.

FASCIÆ.

The **superficial fascia** of the thigh and buttock is continuous above with the fascia of the abdomen and back, internally with that of the perineum, and below with that of the leg. It presents noticeable features in the buttock and groin.

In the buttock the superficial fascia is of considerable thickness, and is usually loaded with fat, whereby it assists in forming the contour of the buttock and the fold of the nates.

In the groin it is divisible into *two layers*: a **superficial fatty layer**, continuous with a similar layer on the front of the abdominal wall above, and over the perineum internally, and a **deeper membranous layer**, which is attached above to the inner half of Poupart's ligament, and to the deep fascia of the thigh just below the outer half of that ligament. Internally it is attached to the pubic arch, and below the level of Scarpa's triangle it blends inseparably with the superficial fatty layer. The separation of these two layers of the superficial fascia is occasioned by the presence between them of the femoral and inguinal lymphatic glands, the internal saphenous vein and its tributaries, and some small arteries. The attachment of the deeper layer of the fascia to the pubic arch and Poupart's ligament cuts off the superficial tissues of the thigh from the perineum and the anterior abdominal wall, and prevents the passage down the thigh of fluid collected in the perineum or beneath the fascia of the anterior abdominal wall.

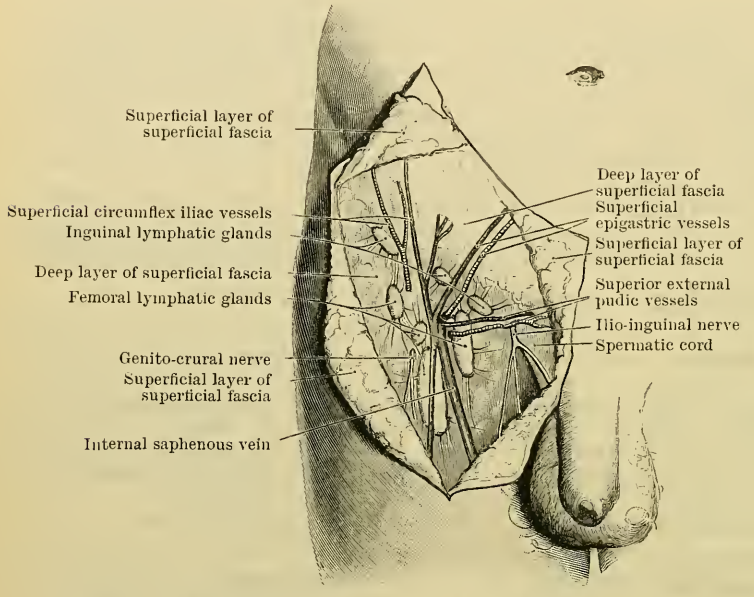


FIG. 273.—THE GROIN. STRUCTURES BETWEEN THE LAYERS OF THE SUPERFICIAL FASCIA.

The **deep fascia** or **fascia lata** forms a tubular investment for the muscles and vessels of the thigh and buttock. It is firmly attached above to the iliac crest, the great sacro-sciatic ligament, the ischium, the pubic arch, the pubic symphysis and crest, and Poupart's ligament. Below, in relation to the knee, it is continuous with the deep fascia of the leg, gains attachment to the patella, the tuberosities of the tibia and the head of the fibula, and forms the lateral ligaments of the patella.

On the front of the thigh the deep fascia is thick and strong. It is pierced by numerous openings for vessels and nerves, the most important of which is the **saphenous opening** for the internal saphenous vein. A femoral hernia passes through this opening to reach the front aspect of the anterior abdominal wall. It is an oval opening of variable size situated just below the inner half of Poupart's ligament, and immediately in front of the femoral vessels. It is covered by the superficial fascia, and by a special layer of fascia, the **cribriform fascia**, a thin perforated lamina, attached to the margins of the opening. The outer edge of the opening is formed by the margin of the *iliac portion* of the fascia lata, which is attached above to the iliac crest and Poupart's ligament; the inner edge is formed by the *pubic portion* of the fascia lata, which is continued upwards behind the femoral sheath, over the adductor longus and pectineus muscles to the ilio-pectineal line and the capsule of the hip-joint. These two layers of the fascia lata are continuous at the lower concave margin of the saphenous opening, forming its **inferior cornu**. As they pass upwards towards the pelvis they occupy different planes, the iliac portion being in front of the femoral sheath, while the pubic portion of the fascia is behind it. The **superior cornu** of the saphenous opening,

placed in front of the sheath, is derived solely from the iliac portion of the fascia lata. It forms a strong triangular band of fascia attached above to the inner half of Poupart's ligament, and is known as the **falciform ligament.** It has an important share in directing the course of a femoral hernia upwards on to the abdominal wall.

Internally in relation to the adductor muscles of the thigh the fascia lata becomes much thinner. *At the knee* it is associated with the tendons of the vasti muscles, and forms the **lateral ligaments of the patella,** attached to the borders of the patella and to the tuberosities of the tibia. *Externally* it gives rise to the

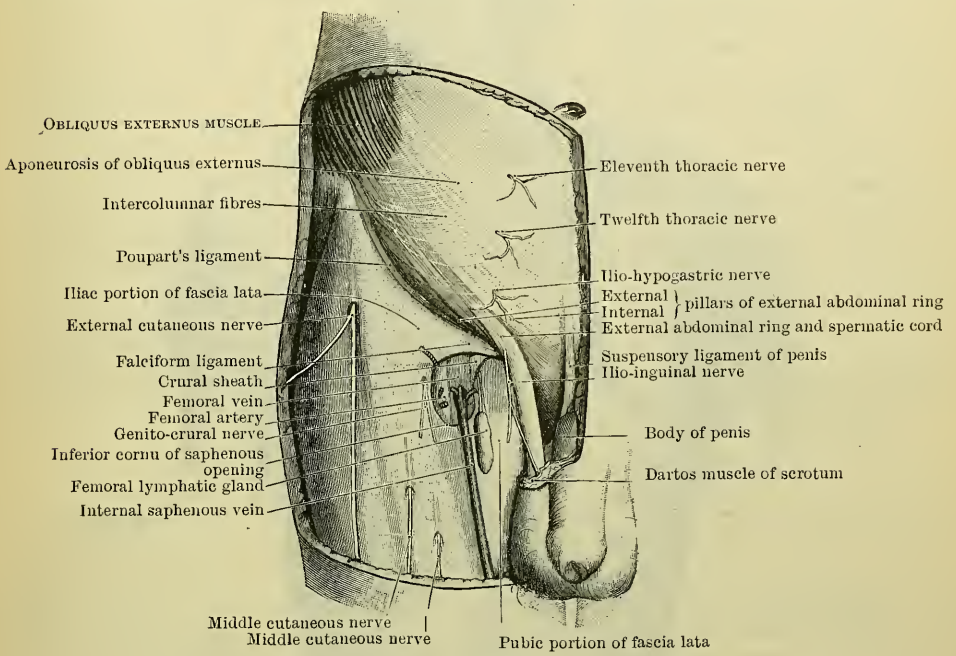


Fig. 274.—The Groin—the Structures seen on removal of the Superficial Fascia.

ilio-tibial band—a broad thick layer of fascia which is attached above to the iliac crest, and receives the insertions of two muscles in the upper part of the thigh—the tensor fasciæ femoris, and part of the gluteus maximus; it is attached below to the capsule of the knee-joint and the outer tuberosity of the tibia. The fascia beneath the tensor fasciæ femoris muscle, continued upwards from the ilio-tibial band, sends a strong band inwards which joins the origin of the rectus femoris and the capsule of the hip-joint.

On either side of the thigh above the knee an intermuscular septum is formed; the **external intermuscular septum** extends inwards from the ilio-tibial band to the external supra-condyloid ridge and linea aspera of the femur, and gives attachment to the vastus externus and crureus in front, and the short head of the biceps behind. The **internal intermuscular septum** is more complex. It is represented by a layer of fascia which forms separate envelopes for the gracilis and sartorius muscles, and in the upper and middle thirds of the thigh encloses the adductor muscles. In the middle third of the thigh the fascia is specially thickened by transverse fibres connecting together the adductor muscles and the vastus internus. This sheet of fascia forms a special aponeurosis beneath the sartorius, which roofs over the femoral artery in Hunter's canal. In the lower third of the thigh the intermuscular septum is closely associated with, and is to a large extent represented by, the tendon of the adductor magnus muscle.

The **fascia lata of the buttock** is thick anteriorly where it covers and gives origin to the gluteus medius, thinner posteriorly over the gluteus maximus, at the upper border of which it splits to enclose the muscle. It is greatly thickened over the

region of the great trochanter, where it forms the insertion of the greater part of the same muscle.

On the **back of the thigh** and over the **popliteal space** the fascia is strengthened by transverse fibres derived from the hamstring muscles. The **popliteal fascia**

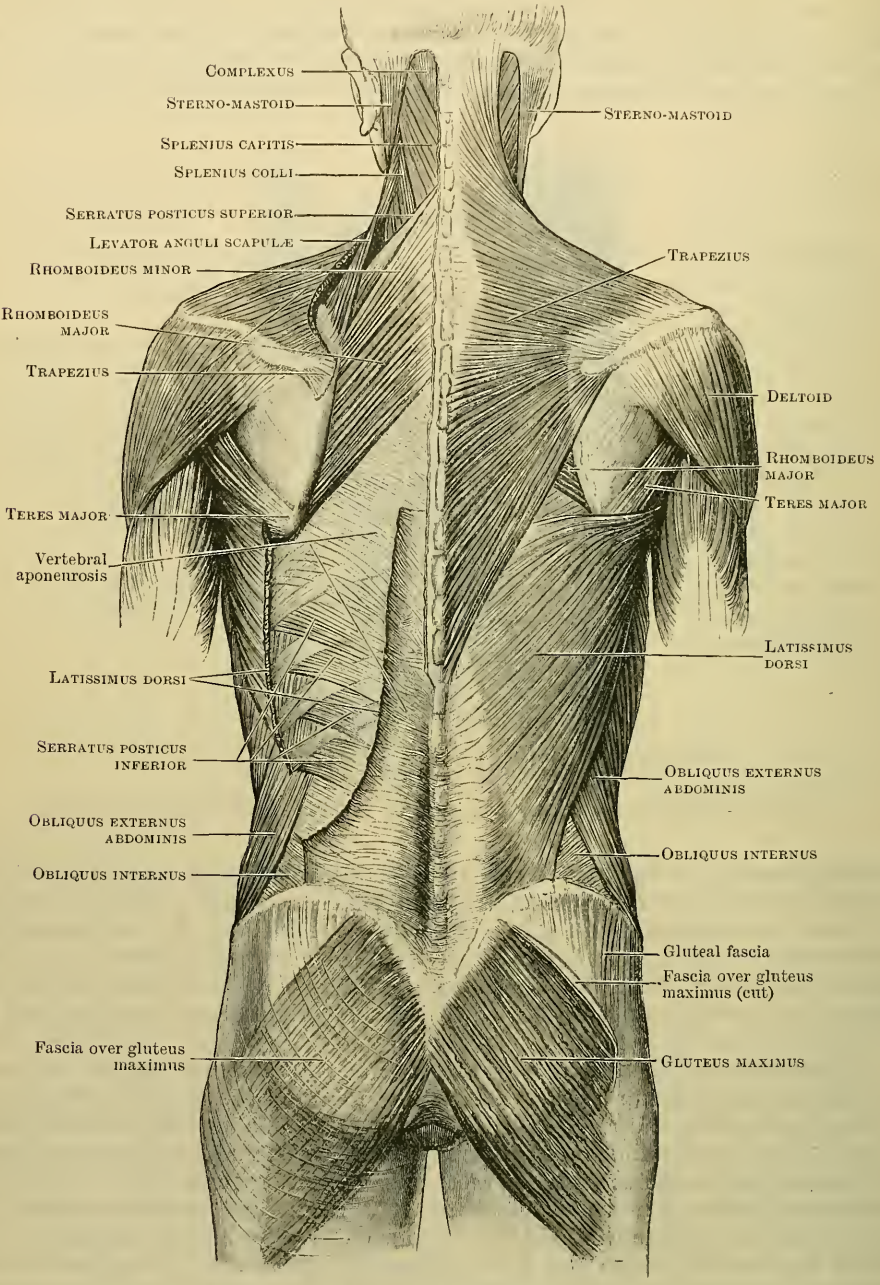


Fig. 275.—Superficial Muscles of the Back.

forming the roof of the popliteal space is specially thick, and is usually pierced by the external saphenous vein.

A **femoral hernia** appears in the thigh through the saphenous opening, thereafter passing upwards over Poupart's ligament to the anterior abdominal wall.

Femoral Sheath.—This is a conical membranous investment for the femoral vessels, prolonged into Scarpa's triangle beneath Poupart's ligament, and con-

tinuous above with the internal fascial lining of the abdominal wall, formed by the fascia transversalis in front and the fascia iliaca behind. The sheath is divided into three compartments—an external space for the artery, an intermediate space for the vein, and an internal channel containing lymphatics, and named the **crural canal.** The wall of this is known as the **crural sheath.** This canal is the passage through which a femoral hernia enters the thigh. Its upper limit is the **crural ring,** placed behind Poupart's ligament in front of the origin of the pectineus muscle from the pubis; it is bounded internally by Gimbernat's ligament, and externally by the femoral vein. In front of it the fascia transversalis forming the sheath is thickened to form the **deep crural arch.** The part of Poupart's ligament in front of the ring is called the **superficial crural arch.** The deep epigastric artery separates the crural ring from the internal abdominal ring. The crural canal ordinarily contains fat which is continuous above with the extra-peritoneal tissue. The crural ring is filled by a plug of fat or a lymphatic gland, constituting the **crural septum.**

The crural canal ends behind the saphenous opening, covered by the cribriform fascia; the falciform ligament crosses over it and conceals its upper portion. The course of a femoral hernia is determined by this band of the fascia lata. The hernia descends through the crural ring, pushing the crural septum before it; it traverses the crural canal, and is directed forwards through the saphenous opening. The anterior part of the hernia being pressed upon and retarded by the crural arches and by the falciform ligament, the posterior part pushes onwards, hooks round the falciform ligament, and is directed upwards over Poupart's ligament. The coverings of a femoral hernia, in addition to peritoneum and extra-peritoneal tissue (crural septum), are crural sheath, cribriform fascia, superficial fascia, and skin.

THE MUSCLES ON THE FRONT OF THE THIGH.

The muscles on the front of the thigh include the sartorius, quadriceps extensor, ilio-psoas, and pectineus muscles.

The **sartorius,** a long strap-like muscle stretching obliquely across the thigh, **arises** by short tendinous fibres from the anterior superior spine of the ilium and half of the notch below it (Fig. 285, p. 369). It passes down the thigh to the inner side of the knee, where it is **inserted** by aponeurotic fibres into the inner surface of the shaft of the tibia just below the inner tuberosity, and by its borders into fascial expansions which join the capsule of the knee-joint and the fascia lata of the leg (Fig. 279, p. 363). An expansion from the upper part of the tendon of insertion is attached along an oblique line, which is directed downwards and backwards, above the attachment of the gracilis, to the internal lateral ligament of the knee-joint, with which it is connected.

The sartorius is superficial in its whole extent. It is so twisted on itself that in the upper third of its length its superficial surface looks forwards, in the lower third inwards, at the side of the knee. It passes diagonally down the thigh, separating the quadriceps extensor externally from the adductor muscles internally. Its upper third forms the outer boundary of Scarpa's triangle; its middle third forms the roof of Hunter's canal; and its lower third, in contact with the inner side of the knee, is separated from the tendon of the gracilis muscle by the long saphenous nerve and a branch of the anastomotic artery. A bursa lies beneath the tendon at its insertion. The sartorius conceals in its upper third the external circumflex vessels and branches of the anterior crural nerve, and it covers the femoral vessels in Hunter's canal.

The **quadriceps extensor** (m. quadriceps femoris) lies between the sartorius on the one hand and the tensor fasciæ femoris and ilio-tibial band on the other; it is composed of four muscles—the rectus femoris, vastus externus, crureus, and vastus internus.

The **rectus femoris** has a double tendinous **origin.** (1) The *straight head* arises from the anterior inferior spine of the ilium (Fig. 282, p. 366); (2) the *reflected head* springs from a rough groove on the dorsum ilii just above the highest part of the acetabulum (Fig. 285, p. 369). A bursa lies beneath this

head of origin. The two heads, bound together and connected to the capsule of the hip-joint by a band of fascia derived from the under surface of the tensor fasciæ femoris (ilio-tibial band), give rise to a single tendon which extends for

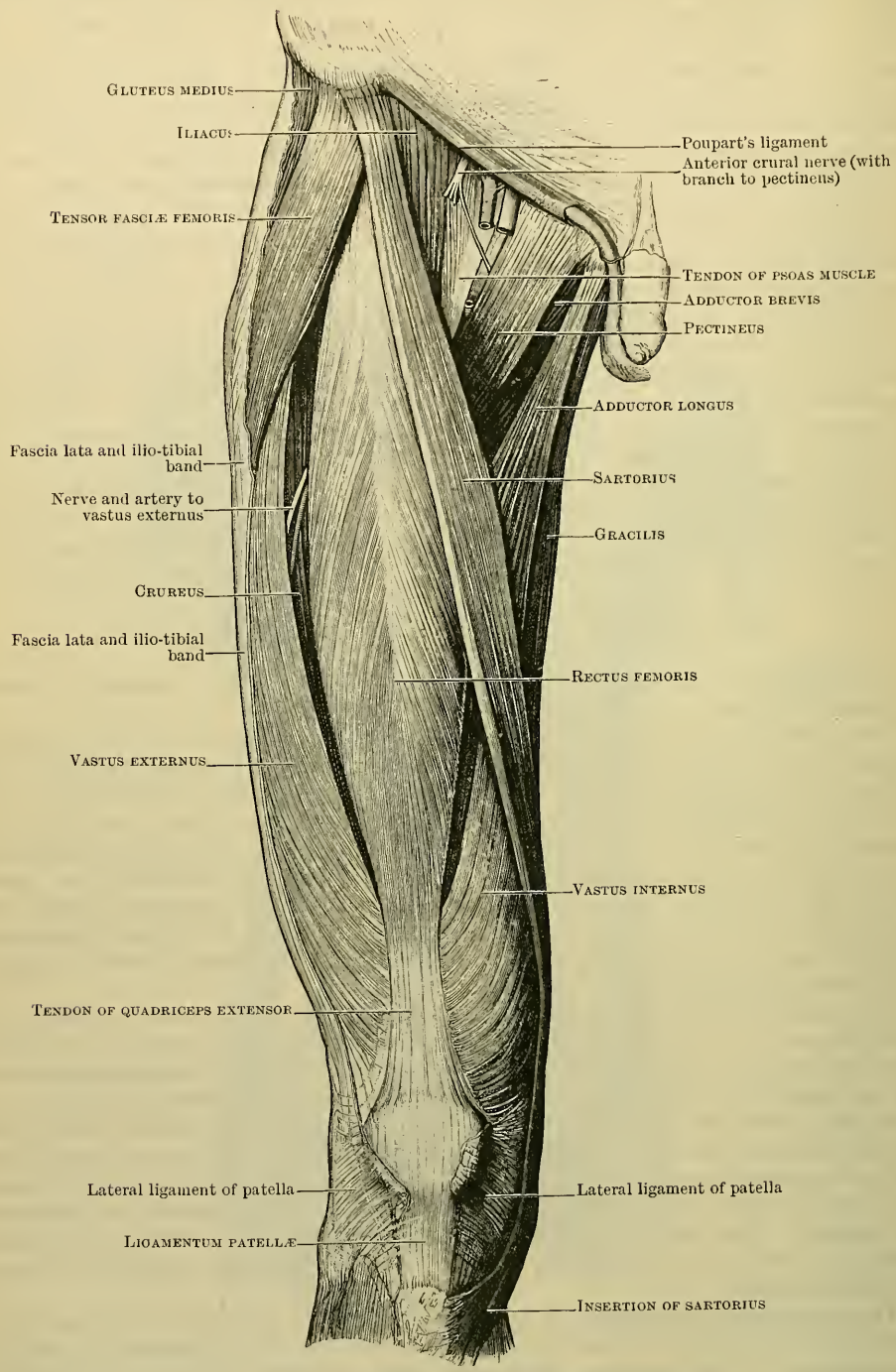


Fig. 276.—The Muscles on the Front of the Thigh.

some distance on the front of the muscle, and from which the muscular fibres arise. The muscular fibres springing from this tendon, and also from a median septal tendon, present a bipennate arrangement, and end below in a broad tendon which passes upwards for some distance along the posterior surface of the muscle. This

tendon gradually narrows towards the knee, and spreading out again, is **inserted** into the upper border of the patella. It receives laterally parts of the insertions of the vasti muscles, and on its deep surface is joined by the tendinous insertion of the crureus.

The rectus femoris is superficial except at its origin, which is covered by the glutei, tensor fasciæ femoris, and sartorius muscles. On its inner side lie the iliacus, sartorius, and vastus internus; on its outer side are the tensor fasciæ femoris and vastus externus. It conceals the crureus muscle and branches of the external circumflex artery and anterior crural nerve. A bursa, which communicates with the synovial membrane of the knee-joint, lies beneath its tendon in front of the lower end of the shaft of the femur.

The **vastus externus** (m. vastus lateralis) has an **origin**, partly fleshy, partly membranous, (1) (slightly) from the capsule of the hip-joint, (2) from the tubercle of the femur, (3) from a concave surface on the front of the shaft of the bone internal to the great trochanter, (4) from the lower border of the great trochanter, (5) from the outer margin of the gluteal ridge of the femur and the tendon of the gluteus maximus, (6) from the upper half of the linea aspera, and (7) from the fascia lata and external intermuscular septum (Fig. 277, p. 361).

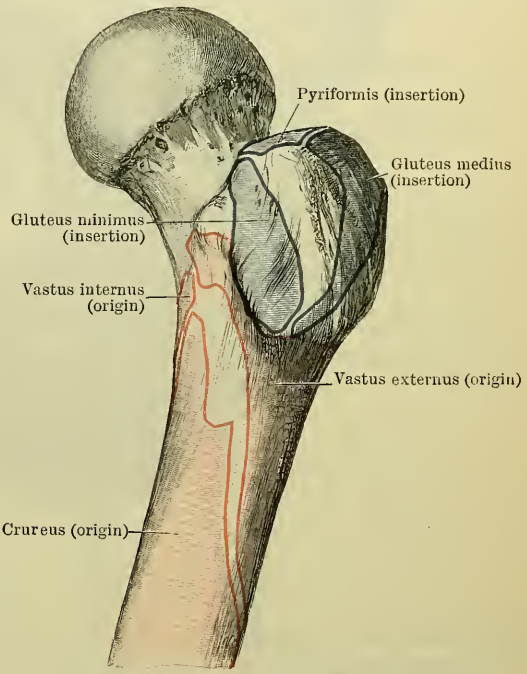


FIG. 277.—MUSCLE-ATTACHMENTS TO THE ANTERIOR SURFACE OF THE UPPER PART OF THE FEMUR.

It forms a thick, broad muscle directed downwards and forwards, and is **inserted** by a broad membranous tendon into (1) the outer border of the tendon of the rectus femoris, (2) the upper and outer border of the patella, and (3) the capsule of the knee-joint, and the external lateral ligament of the patella. The vastus externus is covered superficially by the fascia lata and the ilio-tibial band. A bursa intervenes between it and the membranous insertion of the gluteus maximus: at its inner border is the rectus femoris; and under cover of it, on a deeper plane, is the crureus, which is also to a large extent concealed by the muscle. Between the vastus externus and crureus is the descending branch of the external circumflex artery.

The **vastus internus** (m. vastus medialis) is larger than the vastus externus and has a more extensive **origin**, from (1) the shaft of the femur—from the lower two-thirds or more of the spiral line, the linea aspera, and the upper two-thirds of the line leading from the linea aspera to the internal condyle of the femur; (2) the membranous expansion of the fascia lata which lies beneath the sartorius and forms the roof of Hunter's canal; and (3) the internal intermuscular septum and the tendon of the adductor magnus (Figs. 277, p. 361, and 281, p. 365).

From its origin the muscle is directed downwards and outwards towards the knee; it is **inserted** by a strong aponeurotic tendon into (1) the inner border of the rectus tendon; (2) the upper and inner border of the patella; and (3) the capsule of the knee-joint and the internal lateral ligament of the patella. The vastus internus is superficial except at its origin, which is concealed by the sartorius muscle and femoral vessels. Along its outer side are the rectus and crureus; the muscle conceals the inner side of the shaft of the femur and the crureus, with which it is closely incorporated in its lower two-thirds.

The **crureus muscle** (m. vastus intermedius) **arises** by fleshy fibres (1) from the

upper two-thirds of the shaft of the femur on the anterior and external surfaces, (2) from the lower half of the outer lip of the linea aspera and the upper part of the line leading therefrom to the external condyle, as well as (3) from a corresponding portion of the external intermuscular septum (Fig. 277, p. 361).

For the most part deeply placed, the muscle is directed downwards to an **insertion** into the deep surface of the tendons of the rectus and vasti muscles by means of fibres which join a membranous expansion on its surface.

The crureus is concealed by the rectus and vasti muscles, and externally, in the lower half of the thigh, by the ilio-tibial band. It is closely adherent to the vastus externus muscle in the middle third of the thigh; it is inseparable from the vastus internus below the upper third. Beneath the crureus is the femur;

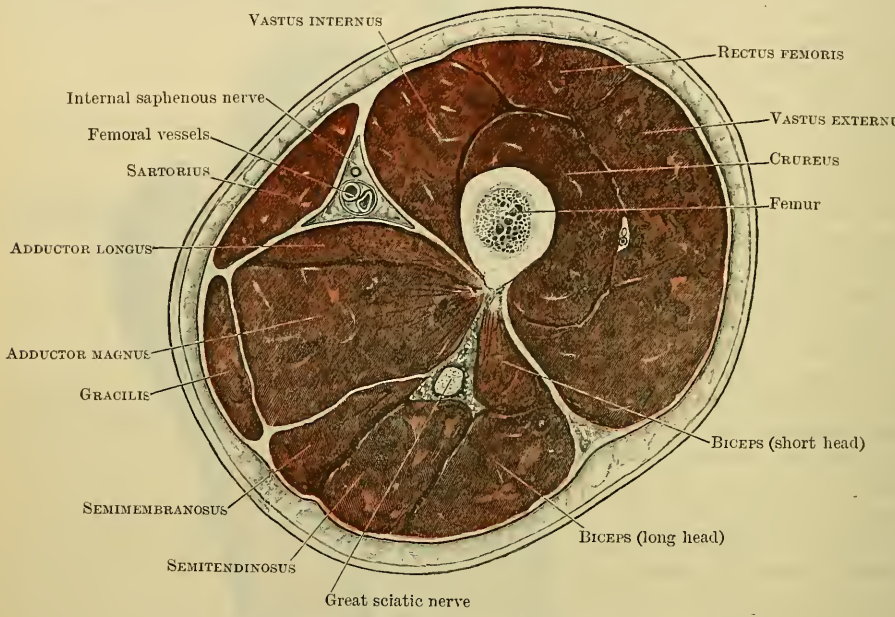


Fig. 278.—Transverse Section of the Thigh (Hunter's Canal).

and in the lower third of the thigh it conceals the subcrureus muscle, a bursa, and the upward prolongation of the synovial membrane of the knee-joint.

The **subcrureus** consists of a number of separate bundles of muscular fibres **arising** beneath the crureus from the lower fourth of the front of the femur, and **inserted** into the synovial membrane of the knee-joint beneath the tendon of the rectus femoris.

The four elements composing the quadriceps extensor muscle have been traced in their convergence to the patella and the lateral ligaments of the patella. Their ultimate **insertion** is into the tibia (Fig. 279, p. 363), by means of the **ligamentum patellæ** and the **lateral ligaments of the patella**. The patella, indeed, is in one sense a sesamoid bone formed in the tendon of the muscle, the ligamentum patellæ being the real tendon of insertion, and the lateral ligaments fascial expansions from its borders. The insertion of the muscle forms the front of the capsule of the knee-joint.

The **ilio-psoas muscle** is a compound muscle, consisting of one or sometimes two elements,—**psoas** (**magnus and parvus**), connecting the femur and pelvic girdle to the axial skeleton; and another element, the **iliacus**, extending between the innominate bone and the femur. The muscles chiefly occupy the posterior wall of the abdomen and false pelvis, their insertions only appearing in the thigh below Poupart's ligament.

The **psoas magnus** (m. psoas major) is a large pyriform muscle, which has an extensive **origin** by fleshy fibres from the vertebral column in the lumbar region. It arises (1) from the intervertebral discs above each lumbar vertebra, and from the

adjacent margins of the vertebræ—from the lower border of the 12th thoracic to the upper border of the 5th lumbar vertebra; (2) it arises also from four aponeurotic arches which pass over the sides of the bodies of the first four lumbar vertebræ; and (3) it has an additional origin posteriorly from the transverse processes of all the lumbar vertebræ. The fibres form a fusiform muscle directed downwards over the pelvic brim and beneath Poupart's ligament, ending in a tendon which is **inserted** into the apex of the lesser trochanter of the femur (Fig. 281, p. 365).

The psoas muscle occupies the posterior abdominal wall, the false pelvis, and the thigh. In the abdomen it lies in the groove alongside the bodies of the lumbar vertebræ, in front of the transverse processes, and is enveloped by a fascia derived from the lumbar aponeurosis. The abdominal viscera in contact with it are: the kidney and colon on both sides, with the duodenum on the right, and the pancreas on the left side. The ureter is in front of it, along with the spermatic or ovarian, the renal and colic vessels. The inferior vena cava is in front of the right muscle; the inferior mesenteric vein is in front of that of the left side. The lumbar plexus is embedded in its substance, and the nerves of distribution emerge from its surface and borders. In the false pelvis the psoas covers the pelvic brim, and is covered by the ureter, the iliac vessels, the ileum on the right side, and the iliac colon on the left side. The vas deferens and spermatic vessels cross over it just above Poupart's ligament. In Scarpa's triangle the tendon is behind the femoral vessels, between the iliacus and pectineus, and in front of the obturator externus muscle and the hip-joint. A bursa, which may be continuous with the synovial cavity of the hip-joint, separates the tendon from the pubis and the capsule of the hip-joint.

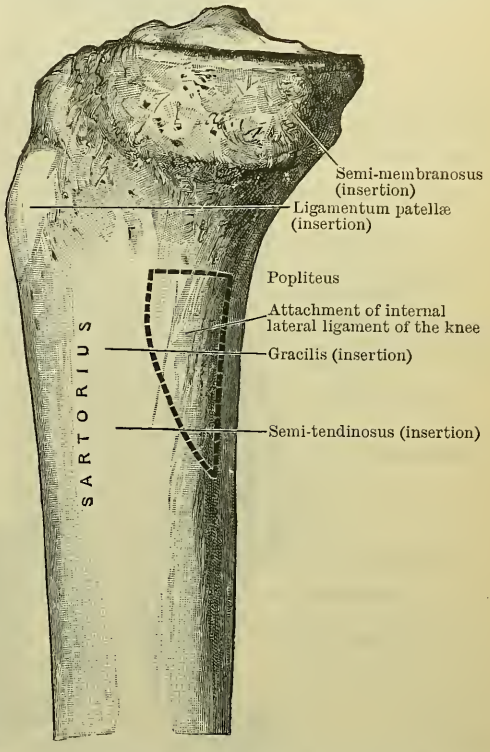


FIG. 279.—MUSCLE-ATTACHMENTS TO THE INNER SIDE OF THE UPPER PART OF THE TIBIA.

The **psoas parvus** (m. psoas minor) is often absent (40 per cent). It **arises** by fleshy fibres from the intervertebral disc between the last thoracic and first lumbar vertebræ, and from the contiguous margins of these vertebræ. The muscle is closely apposed to the anterior surface of the psoas magnus. It forms a slender fleshy belly, and is **inserted** by a narrow tendon into the middle of the ilio-pectineal line and the ilio-pectineal eminence, its margins blending with the fascia covering the psoas magnus.

The **iliacus muscle arises** by fleshy fibres, mainly from a horseshoe-shaped origin around the margin of the iliac fossa; it has additional origins also from the ala of the sacrum, the anterior sacro-iliac, lumbo-sacral, and ilio-lumbar ligaments, and outside the pelvis, from the upper part of the ilio-femoral band. It is a fan-shaped muscle, its fibres passing downwards over the hip-joint towards the small trochanter of the femur. It is **inserted** by fleshy fibres (1) into the outer side of the tendon of the psoas magnus; (2) into the concave anterior and upper surfaces of the small trochanter; and (3) into the shaft of the femur below the small trochanter for about an inch (Fig. 281, p. 365); and (4) by its most external fibres into the capsule of the hip-joint. These fibres are often separate, forming the **iliacus minor**, or **ilio-capsularis.**

The muscle occupies the false pelvis and Scarpa's triangle. It forms the back

wall of the false pelvis and is covered anteriorly by the iliac fascia. It is in contact with the cæcum on the right side and the iliac colon on the left side. The psoas muscle lies along its inner border, with the anterior crural nerve in the interval between them. After passing beneath Poupart's ligament, and over the capsule of the hip-joint, the muscle occupies the outer part of the floor of Scarpa's triangle, internal to the sartorius and rectus femoris muscles.

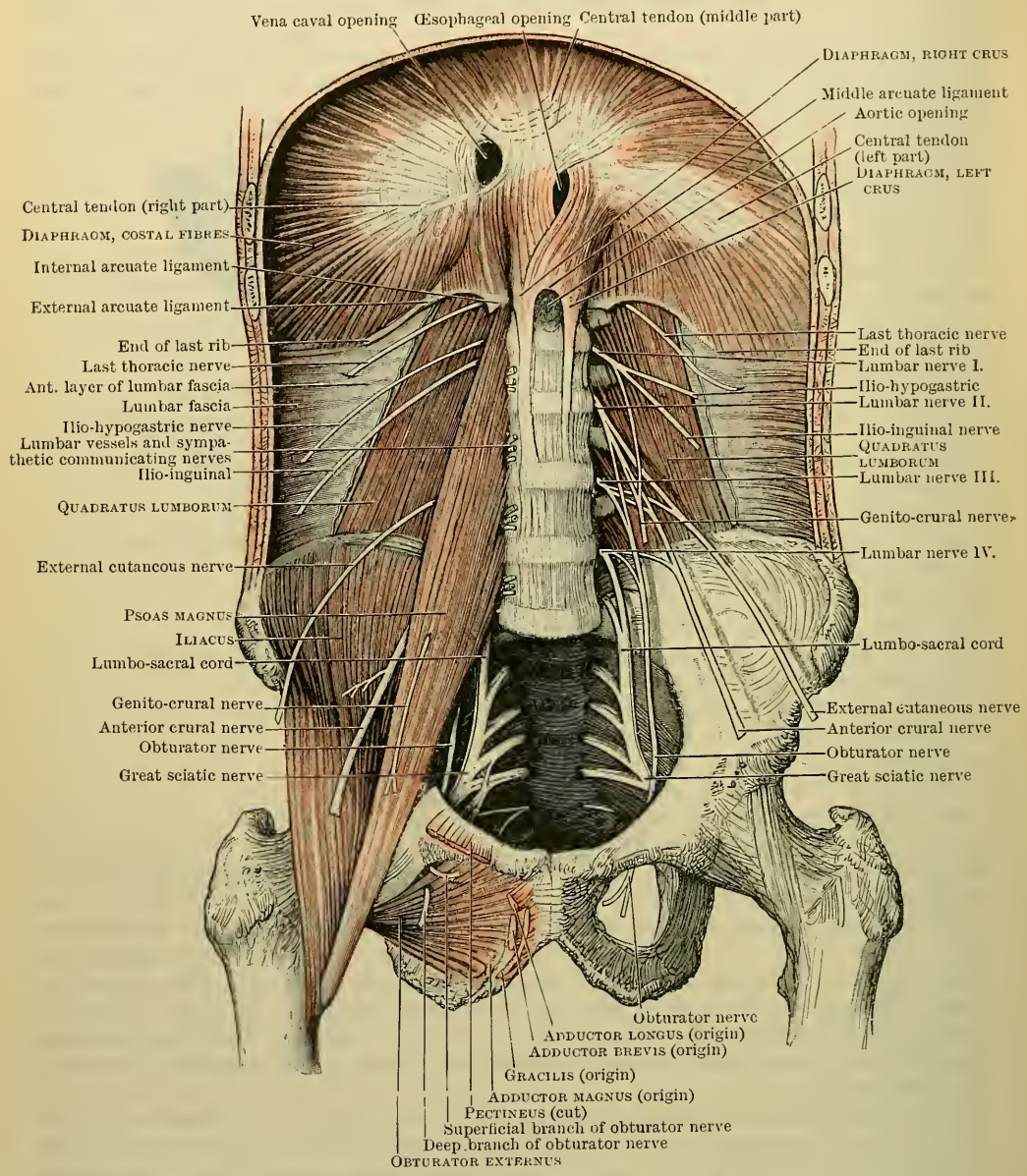


Fig. 280.—View of the Posterior Abdominal Wall, to show the Muscles and the Nerves of the Lumbo-Sacral Plexus.

The **pectineus** muscle arises by fleshy fibres from the sharp anterior portion of the ilio-pectineal line of the pubis, and from the triangular surface of the pubic bone in front of this (Fig. 282, p. 366). It also arises from the femoral surface of Gimbernat's ligament, and from the pubic portion of the fascia lata which covers it. Forming a broad muscular band, it is directed obliquely downwards, backwards, and outwards, to be **inserted** by a thin flat tendon about two inches in length into the upper half of the pectineal line leading from the back of the

small trochanter of the femur towards the linea aspera; its lower attachment being placed in front of the insertion of the adductor brevis muscle (Fig. 281, p. 365).

The pectineus forms a part of the floor of Scarpa's triangle. Covered by the pubic portion of the fascia lata, it is partially concealed by the femoral vessels and the insertion of the ilio-psoas. It lies in front of the pubic bone, the obturator externus and adductor brevis muscles, and the superficial part of the obturator nerve. Its outer border is separated from the psoas by the internal circumflex vessels. Its inner border is in contact above with the adductor longus, but is separated from it below by the deep femoral vessels. The muscle may be occasionally divided into inner and outer parts, the former innervated by the obturator, the latter by the anterior crural nerve.

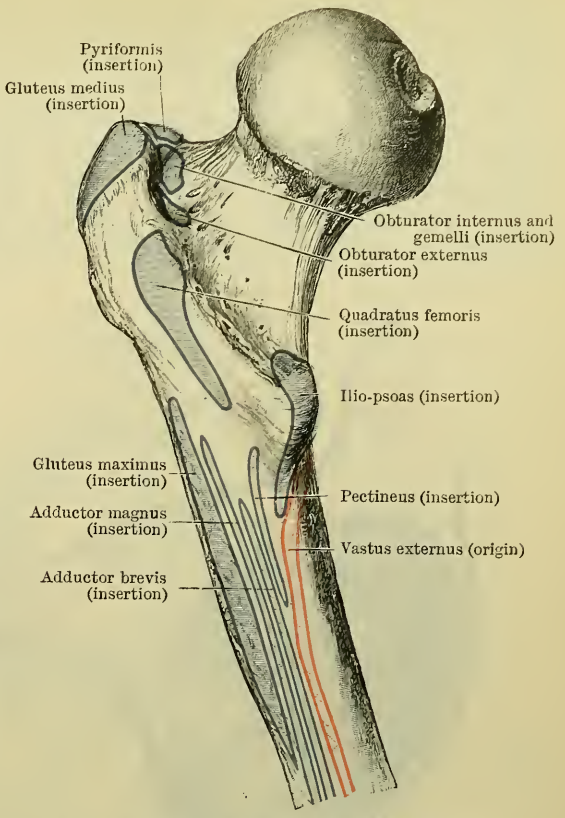


FIG. 281.—MUSCLE-ATTACHMENTS TO THE POSTERIOR ASPECT OF THE UPPER PART OF THE FEMUR.

THE MUSCLES ON THE INNER SIDE OF THE THIGH.

The muscles on the inner side of the thigh include the adductors of the femur—the adductor longus, adductor brevis, and adductor magnus; the gracilis, and the obturator externus.

The **gracilis muscle** is a long flat band placed on the inner side of the thigh and knee. It arises by a thin aponeurotic tendon from the lower half of the edge of the symphysis pubis, and for a similar distance from the border of the adjoining part of the pubic arch (Fig. 282, p. 366). Its flattened fleshy belly passes down on the inner side of the thigh to the knee, where it ends in a tendon, which expands to be inserted into the inner side of the shaft of the tibia just below the inner tuberosity, behind the sartorius and above and in front of the semitendinosus (Fig. 279, p. 363). It is separated from the sartorius tendon by a bursa, and beneath its tendon is another bursa common to it and the semitendinosus.

The gracilis is superficial in its whole extent, except at its insertion which is concealed by the insertion of the sartorius muscle. Its deep surface covers the borders of the adductor longus and adductor magnus muscles, as well as the superficial part of the obturator nerve. At the inner side of the knee it lies between the sartorius and semitendinosus.

The **adductor longus** is a triangular muscle arising by a rounded tendon from the anterior surface of the body of the pubis in the angle between the crest and symphysis (Fig. 282, p. 366). Extending downwards and outwards, it is inserted into the middle two-fourths of the inner lip of the linea aspera in front of the adductor magnus. Lying in the same plane as the pectineus, the adductor longus is in contact with that muscle near its origin, but is separated from it below by an interval through which the deep femoral vessels pass. Its inner border is in contact with the gracilis and sartorius muscles. Its anterior surface forms part of the floor of Scarpa's triangle above, part of the floor of Hunter's canal below. It is covered near its insertion by the sartorius and the femoral vessels, and it is connected to

the origin of the vastus internus by an aponeurotic expansion of fascia beneath the sartorius, forming the roof of Hunter's canal. Its posterior surface is in relation with the adductor brevis and the adductor magnus muscles, the deep femoral vessels, and the superficial part of the obturator nerve. The adductor longus may be double, or more or less fused with the pectineus.

The **adductor brevis** is a large muscle which **arises** by fleshy and short tendinous fibres from an elongated oval surface on the front of the body and upper part of the descending ramus of the pubis, surrounded by the other muscles of this group (Fig. 282, p. 366). Directed downwards and outwards, the muscle expands, to be **inserted** by a short aponeurotic tendon, behind the insertion of the pectineus, into the lower two-thirds of the line leading from the small trochanter of

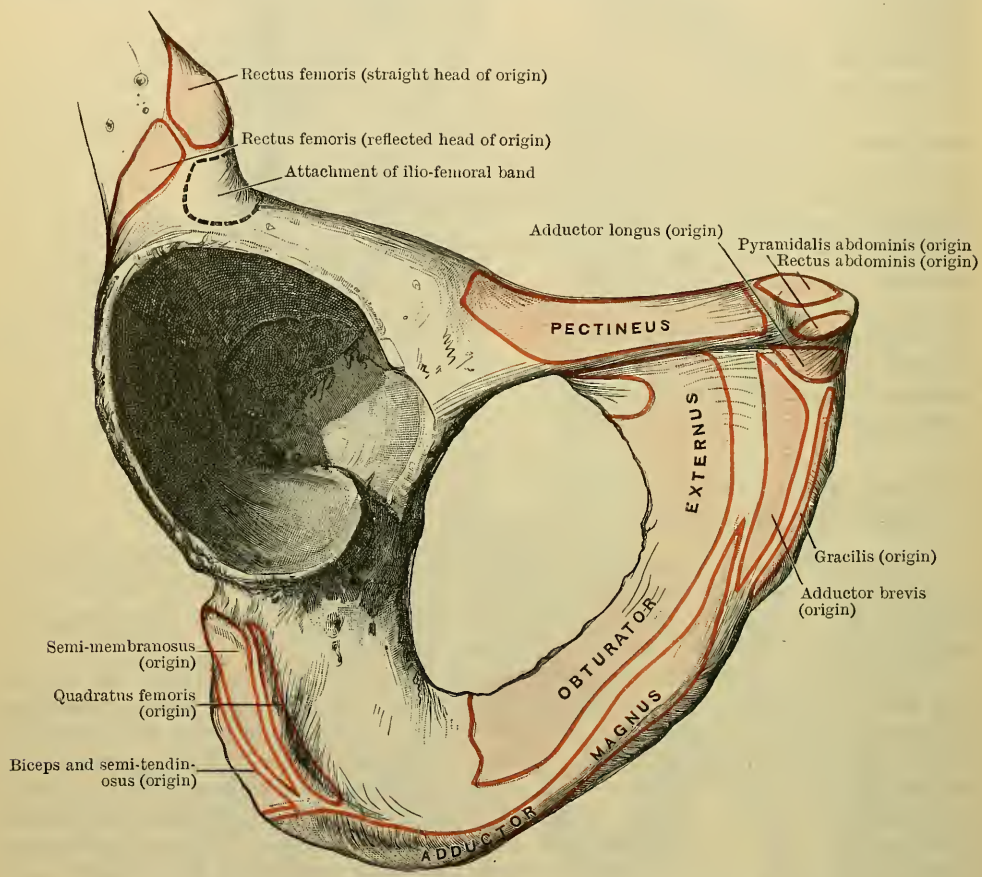


Fig. 282.—Muscle-Attachments to the outer surface of the Pubis and Ischium.

the femur to the linea aspera, and to the upper fourth of the linea aspera itself (Fig. 286, p. 370).

The adductor brevis is the central muscle of the adductor group. It is almost wholly concealed by the pectineus and adductor longus. It rests upon the adductor magnus; at its upper border is the obturator externus, separated from it by the internal circumflex vessels; at its lower border is the adductor longus, separated by the deep femoral vessels. It separates the superficial and deep parts of the obturator nerve in their course down the thigh.

The **adductor magnus**, the largest of the adductor group, is a roughly triangular muscle **arising** mainly by fleshy fibres by a curved origin from the lower part of the outer border and a large portion of the adjoining inferior surface of the ischial tuberosity, from the edge of the ischial ramus, and from the anterior surface of the descending ramus of the pubis, its most anterior fibres arising between the obturator externus and adductor brevis (Figs. 282, p. 366, and 285, p. 369).

Its upper fibres are directed horizontally outwards from the pubis towards the upper part of the femur; the lowest fibres are directed downwards from the ischial tuberosity to the internal condyle of the femur; while the intermediate fibres radiate obliquely outwards and downwards. The muscle is **inserted** by tendinous fibres (1) into the space below the insertion of the quadratus femoris, above the linea aspera; (2) into the whole length of the linea aspera; (3) into the internal supracondyloid ridge of the femur; (4) into the adductor tubercle on the internal condyle of the femur; and (5) into the internal intermuscular septum (Fig. 286, p. 370). The part of the muscle attached to the space above the linea aspera is often separated from the rest as the **adductor minimus**. The attachment of the muscle into the supracondyloid ridge is interrupted for the passage of the

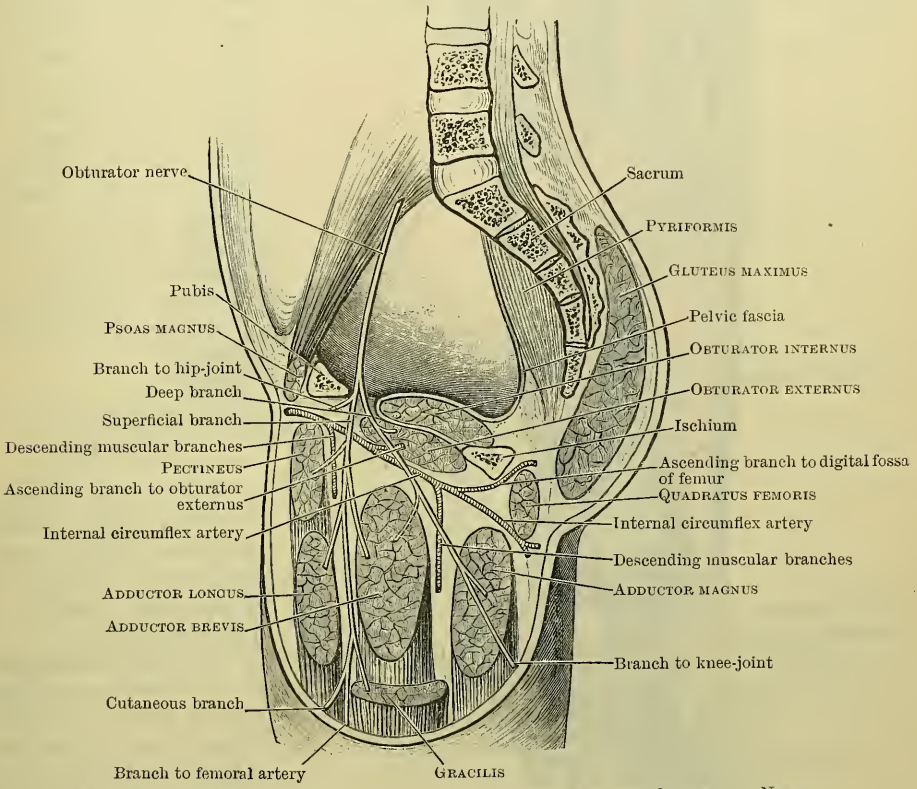


Fig. 283.—Scheme of the Course and Distribution of the Obturator Nerve.

femoral vessels to the popliteal space. The attachment to the internal condyle is by means of a strong tendon which receives the fibres arising from the ischium (the part of the muscle associated with the hamstring group). This tendon is closely connected with the internal lateral ligament of the knee-joint.

The adductor magnus intervenes between the other adductor muscles in front and the hamstring muscles behind. It is concealed anteriorly by the pectineus, adductor brevis, adductor longus, and sartorius. The deep femoral artery lies on it above. It forms the floor of Hunter's canal below, where the femoral vessels lie upon it. The hamstring muscles and great sciatic nerve are behind the adductor magnus; the obturator externus and quadratus femoris are at its upper border; and along its inner border are the gracilis and sartorius muscles.

The **obturator externus** is placed deeply under cover of the previous muscles. It is a fan-shaped muscle lying horizontally in the angle between the hip bone and the neck of the femur. It **arises** from the outer surface of the pubis and ischium, which form the inferior half of the margin of the thyroid foramen, and from the corresponding portion of the outer surface of the obturator membrane (Figs. 282, p. 366, and 285, p. 369). Its fibres converge towards the great trochanter, and

end in a stout tendon which, after passing below and behind the hip-joint, is **inserted** into the digital fossa of the great trochanter (Figs. 286, p. 370, and 289, p. 371). The inferior surface of the muscle is in contact with the pectineus, adductor brevis, and adductor magnus muscles, separated from them by the internal circumflex vessels. The superior surface is in relation to the obturator membrane and the neck of the femur. The tendon lies below and behind the capsule of the hip-joint, and near its insertion appears in the buttock (under cover of the gluteus maximus) between the inferior gemellus and quadratus femoris muscles.

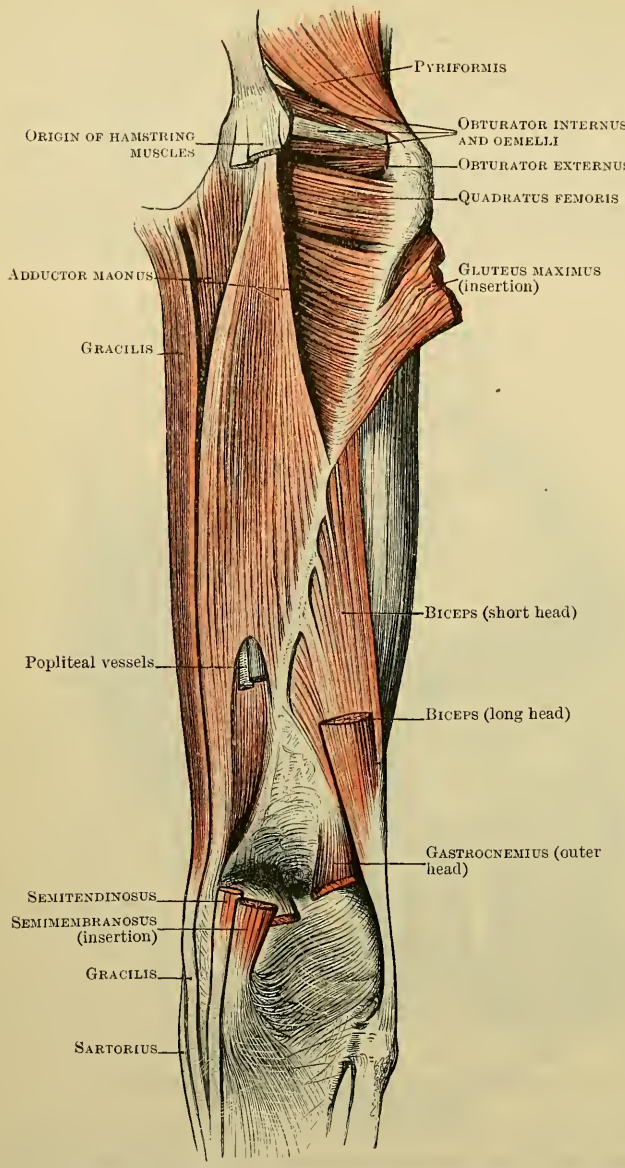


Fig. 284.—The Posterior Surface of the Thigh (superficial muscles removed).

THE MUSCLES OF THE BUTTOCK.

This group includes the three glutei muscles, the tensor fasciæ femoris, pyriformis, obturator internus and gemelli, and quadratus femoris.

The **gluteus maximus** is a large quadrilateral muscle, with a crescentic **origin**, from (1) a portion of the area on the dorsum ilii above the superior curved line (Fig. 285, p. 369); (2) the tendon of the erector spinæ; (3) the posterior surface of the sacrum and coccyx (Fig. 311, p. 396); and (4) the posterior surface of the great sacro-sciatic ligament. The fibres which form its upper and outer border take origin directly from the fascia lata which envelopes the muscle. The muscle forms a large fleshy mass, whose fibres are directed obliquely outwards over the buttock, invested by the fascia lata, and are **inserted** by short tendinous fibres, partly into the fascia lata over the great trochanter of the femur (joining the ilio-tibial band), and partly into the gluteal ridge (Fig. 286, p. 370). The fascia lata receives the insertion of the whole of the superficial fibres of the muscle and the upper half of the deep fibres. The lower half of the deep portion of the muscle is inserted for the most part into the gluteal ridge; but the lowest fibres of all are inserted into fascia lata, and are thereby connected with the external intermuscular septum and the origin of the short head of the biceps.

The gluteus maximus is the coarsest and heaviest muscle in the body. By its

weight it helps to form the fold of the nates. It is superficial in its whole extent. The gluteus medius is visible at its upper border, covered by the fascia lata; at its lower border the hamstring muscles and great sciatic nerve appear on their way down the thigh. The muscle conceals the bones from which it arises, along with the great sciatic ligament, the ischial tuberosity, and the great trochanter of the femur. It also conceals the gluteus medius and pyriformis, with a branch of the gluteal artery between them; the obturator internus and gemelli, with the sciatic vessels and nerves, the pudic vessels and nerve, and the muscular branches of the sacral plexus above them, and the obturator externus and a branch of the internal circumflex artery below them; the quadratus femoris and upper part of the adductor magnus muscles, with the internal circumflex vessels between them. It covers the origins of the hamstring muscles, and by its insertion into the fascia lata,

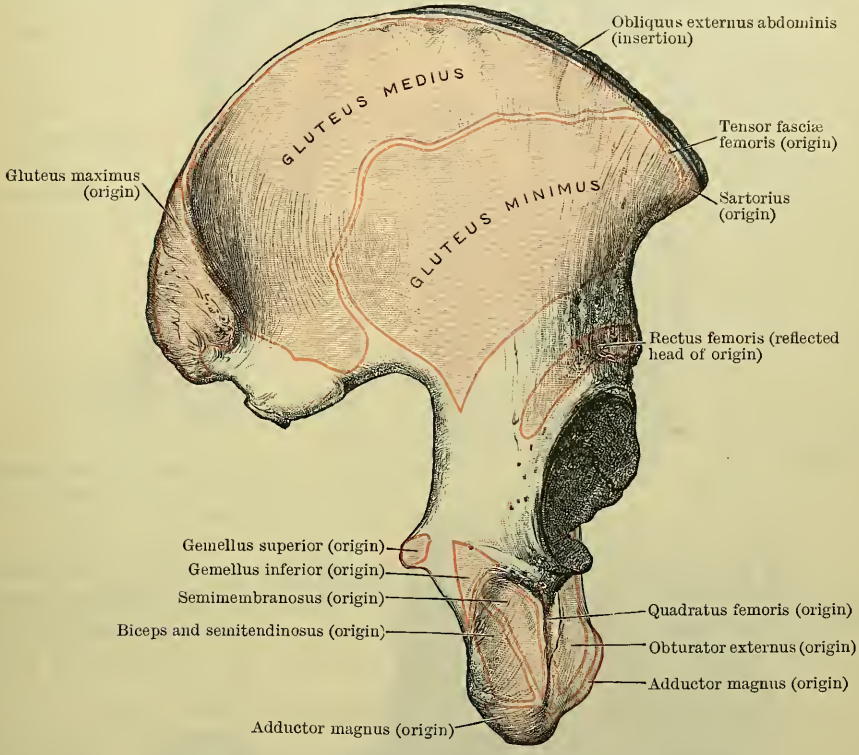


FIG. 285.—MUSCLE-ATTACHMENTS TO THE DORSUM ILII AND TUBER ISCHII.

the vastus externus. The first perforating artery pierces the attachment of the muscle to the gluteal ridge. Three bursæ are beneath it: one (not always present) over the tuberosity of the ischium, a second over the outer side of the great trochanter, and a third over the vastus externus. The fibres of the gluteus maximus arising from the coccyx may form a separate muscle (**agitator caudæ**).

The **tensor fasciæ femoris** (m. tensor fasciæ latæ), lying on the same plane as the gluteus maximus, **arises** from the iliac crest and the dorsum ilii just external to the anterior superior spine, and from the fascia covering its outer surface (Fig. 285, p. 369). Invested like the gluteus maximus by the fascia lata, it is **inserted** about the level of the great trochanter of the femur into the fascia, which forms the **ilio-tibial band** (p. 357).

The tensor fasciæ femoris muscle is superficially placed, and is enclosed in a strong investment of the fascia lata, the deeper layer of which is prolonged up to join the tendon of the rectus femoris and the capsule of the hip-joint. The muscle is placed along the anterior borders of the gluteus medius and gluteus minimus, and conceals branches of the gluteal and external circumflex vessels and the termination of the superior gluteal nerve. The sartorius muscle is adjacent to it anteriorly at

its origin, and is separated from it below by the rectus femoris.

The **gluteus medius** arises by fleshy and tendinous fibres (1) from the dorsum ilii, between the iliac crest and the superior curved line above and the middle curved line below (Fig. 285, p. 369), and (2) from the strong fascia lata covering its surface anteriorly. It is a fan-shaped muscle, its fibres converging to the great trochanter, to be **inserted** by a strong, short tendon into the postero-superior angle of the trochanter, and into a well-marked diagonal line on its outer surface (Figs. 286, p. 370, 277, p. 361, and 289, p. 371).

The muscle is covered along its anterior border by the tensor fasciæ femoris. Its surface is covered over by the fascia lata and the gluteus maximus. Its inferior border is separated from the pyriformis muscle by the superficial branch of the gluteal artery. Its deep surface is in contact with the gluteus minimus, the gluteal vessels, the superior gluteal nerve, and the insertion of the pyriformis muscle. A bursa is placed beneath the tendon at its insertion.

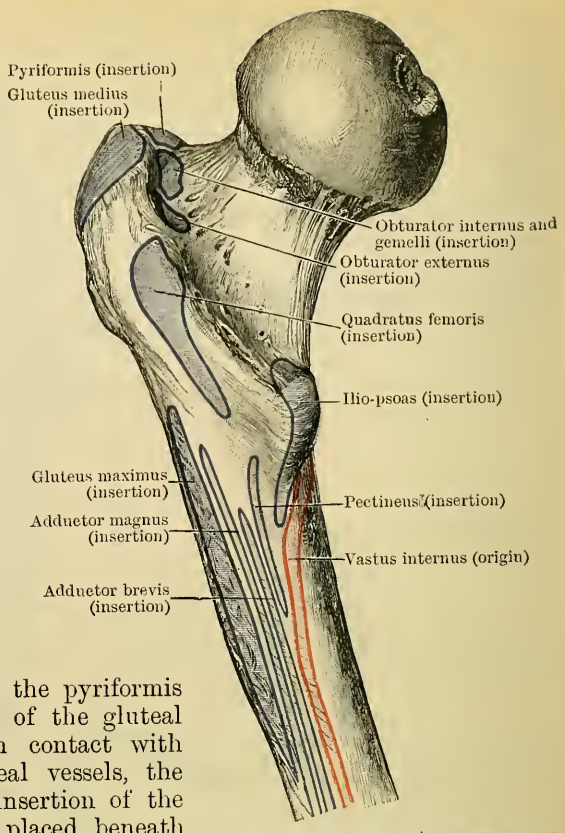


FIG. 286.—MUSCLE-ATTACHMENTS TO THE POSTERIOR ASPECT OF THE UPPER PART OF THE FEMUR.

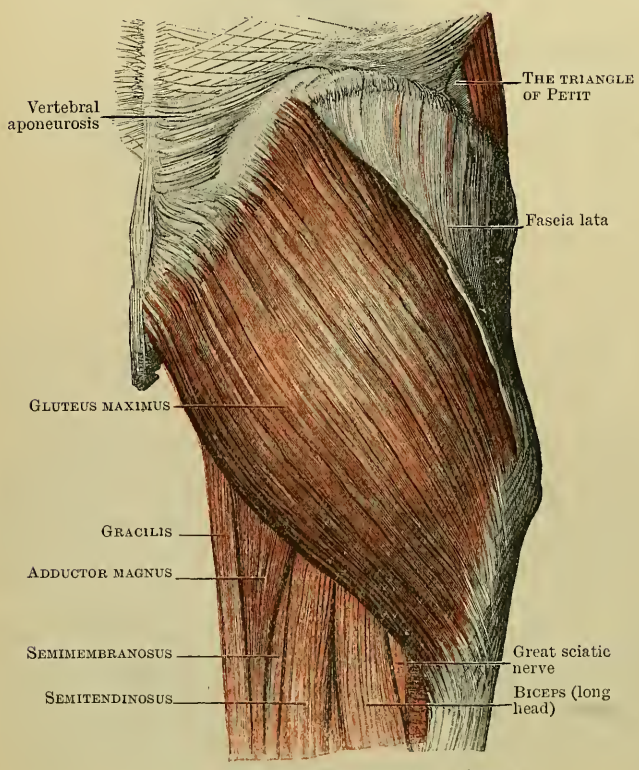


FIG. 287.—THE GLUTEUS MAXIMUS MUSCLE.

The **gluteus minimus** arises by fleshy fibres from the dorsum ilii between the middle and inferior curved lines (Fig. 285, p. 369). This muscle is fan-shaped and its fibres converge to the antero-superior angle of the great trochanter, to be **inserted** into the anterior surface of the trochanter, and sometimes also into the front part of the upper border (Figs. 277, p. 361, and 289, p. 371). It is also inserted into the capsule of the hip-joint. The muscle is concealed by the tensor fasciæ femoris and gluteus medius. The pyriformis is in contact with its inferior border, and beneath it are the capsule of the

hip-joint and the reflected tendon of the rectus femoris muscle. A bursa is placed beneath the tendon in front of the great trochanter.

The **pyriformis** is one of the few muscles connecting the lower limb to the axial skeleton. It **arises** (1) within the pelvis from the pedicles of the second, third, and fourth sacral vertebræ, and from the adjacent part of the bone external to the anterior sacral foramina; passing outwards through the great sacro-sciatic foramen, it receives an origin (2) from the upper margin of the great sciatic notch of the ilium, and (3) from the pelvic surface of the great sacro-sciatic ligament. In the buttock it forms a rounded tendon, which is **inserted** into a facet on the upper border and inner aspect of the great trochanter of the femur, partly surrounding the insertion of the obturator internus (Figs. 286, p. 370, 277, p. 361, and 289, p. 371).

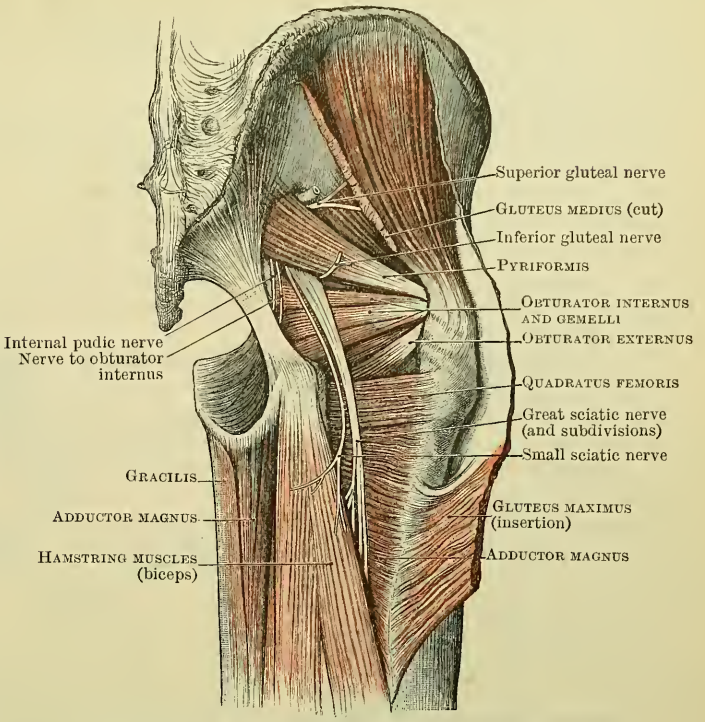


Fig. 288.—The Muscles and Nerves of the Buttock.

The gluteus maximus is reflected; and the gluteus medius is cut in part to show the gluteus minimus.

The pyriformis, besides appearing in the buttock, lines the posterior wall of the pelvis. In the pelvis it lies behind the rectum, covered by a thin layer of the parietal pelvic fascia. In the buttock it is covered by the gluteus maximus, and at its insertion by the gluteus medius, and it lies upon the ilium and the capsule of the hip-joint. At its upper border are the gluteus medius and gluteus minimus, separated by the superior gluteal nerve and the gluteal artery; its lower border is separated from the gemelli and obturator internus by an interval in which the sciatic and pudic vessels and the nerves of the sacral plexus appear. The anterior fibres of the muscle may be separate.

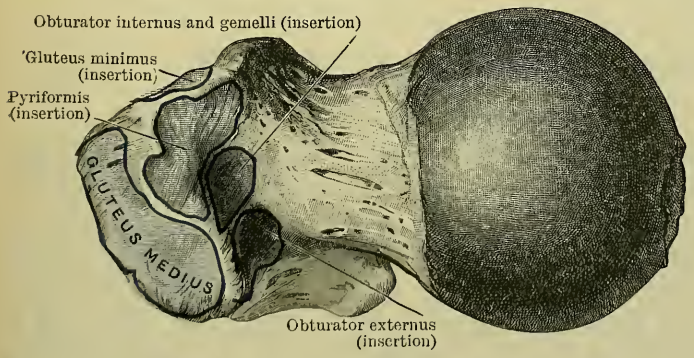


Fig. 289.—Muscle-Attachments to the Upper Aspect of the Great Trochanter of the Femur.

The **obturator internus** arises by fleshy fibres on the pelvic aspect of the hip bone, (1) from the whole of the margin of the thyroid foramen (except the obturator notch, and a portion posteriorly opposite the small sciatic notch); (2) from the surface of the obturator membrane; (3) from the whole of the pelvic surface of

the hip bone behind and above the thyroid foramen; and (4) slightly from the parietal pelvic fascia covering it internally. It is a fan-shaped muscle, and its fibres converging to the lesser sacro-sciatic foramen, give rise to several tendons which hook round the margin of the foramen (a bursa intervening), and after traversing the buttock, unite together to be **inserted** into a facet on the inner surface of the great trochanter of the femur above the digital fossa (Figs. 286, p. 370, and 289, p. 371).

In the pelvis the muscle occupies the lateral wall, covered by the parietal (obturator) layer of pelvic fascia, which separates it from the pelvic cavity above and the ischio-rectal fossa below. It is separated from the contents of the pelvis, above by the peritoneum and extra-peritoneal fat, below by the fat in the ischio-rectal fossa. The internal pudic vessels and nerve cross it in the outer wall of the fossa in a special sheath of the fascia. In the buttock the tendon is embraced by the gemelli muscles which are attached to its upper and lower margins. The tendon is crossed by the sciatic vessels and nerves, and lies against the upper and back part of the capsule of the hip-joint.

The **gemelli muscles** form accessory portions of the obturator internus. They are two in number, **superior** and **inferior**, and are wholly composed of fleshy fibres.

The **superior gemellus arises** from the gluteal surface of the ischial spine and from the upper part of the margin of the lesser sciatic notch (Fig. 285, p. 369). It is **inserted** into the upper margin and superficial surface of the tendon of the obturator internus muscle.

The **gemellus inferior arises** from the upper part of the gluteal surface of the ischial tuberosity and the lower part of the margin of the lesser sciatic notch (Fig. 285, p. 369). It is **inserted** into the lower margin and superficial aspect of the tendon of the obturator internus.

The **quadratus femoris arises** from the outer margin of the ischial tuberosity (Figs. 282, p. 366, and 285, p. 369), and is **inserted** into the quadrate tubercle and quadrate line of the femur (Fig. 286, p. 370). The muscle is placed beneath the gluteus maximus, and is crossed by the sciatic vessels and nerves. Its origin is concealed by the hamstring muscles. Its deep surface is in contact with the obturator externus muscle and the small trochanter of the femur, a bursa intervening. Its upper border is separated from the inferior gemellus by an interval, containing the tendon of the obturator externus and the ascending branch of the internal circumflex artery. Its lower border is separated from the upper margin of the adductor magnus by the internal circumflex vessels. The muscle is not infrequently fused with the adductor magnus.

THE MUSCLES ON THE BACK OF THE THIGH.

The Hamstring Muscles.

The muscles comprised in this series include the biceps, semitendinosus and semimembranosus. A part of the adductor magnus, already described, also belongs morphologically to this group.

The **biceps flexor cruris** (m. biceps femoris) has a double **origin**. (1) *Its long head* arises by means of a tendon, in common with the semitendinosus, from the lower and inner facet upon the tuberosity of the ischium (Figs. 282, p. 366, and 285, p. 369) and from the great sacro-sciatic ligament. This head, united for a distance of two to three inches with the semitendinosus, forms a separate fleshy mass, which extends to the lower third of the thigh, to end in a tendon joined by the short head of the muscle. (2) *The short head* arises separately by fleshy and tendinous fibres (1) from the whole length of the outer lip of the linea aspera and the upper two-thirds of the external supra-condyloid ridge of the femur, and (2) from the external intermuscular septum for a corresponding extent. The upper limit of its origin is sometimes blended with the insertion of the lowest fibres of the gluteus maximus. The fibres of the short head, directed downwards, join the tendon of the long head, and the muscle is **inserted** (1) into the head of the

fibula by a strong tendon, which is split into two parts by the long external lateral ligament of the knee-joint; (2) by a slip attached to the outer tuberosity of the tibia; and (3) along its posterior border by a fascial expansion which connects the tendon with the popliteal fascia.

The long head of the biceps is concealed at its origin by the gluteus maximus muscle. In the lower two-thirds of the thigh it is superficially placed, with the semitendinosus and semimembranosus on its inner side. It conceals the great sciatic nerve, the origins of the semimembranosus and quadratus femoris, the adductor magnus, and the short head of the muscle. The united heads assist in

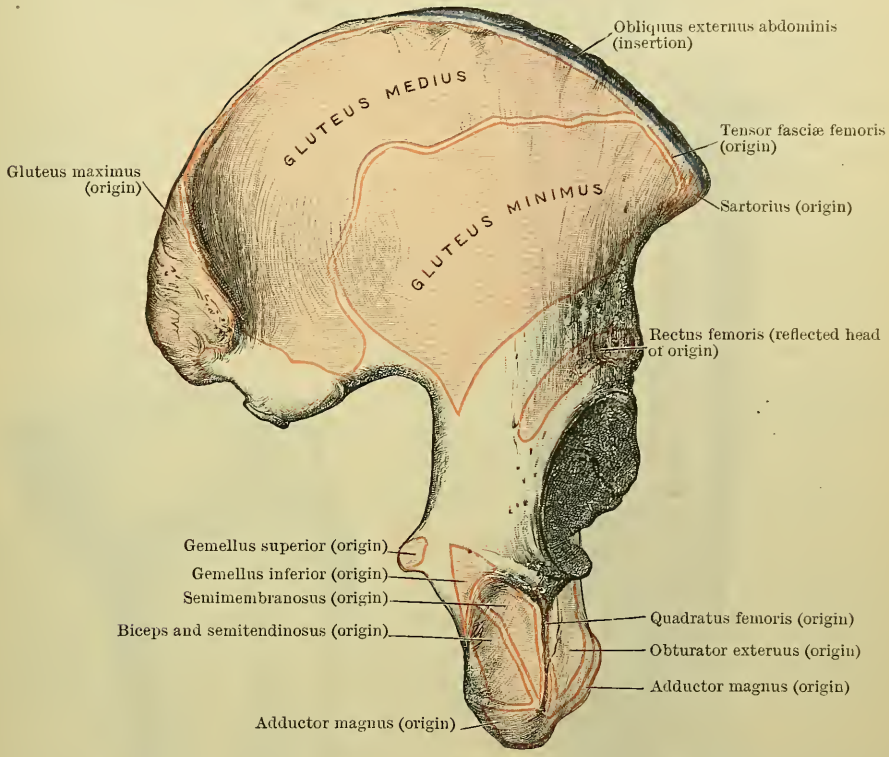


FIG. 290.—MUSCLE-ATTACHMENTS TO THE DORSUM ILII AND TUBER ISCHII.

forming the outer boundary of the popliteal space, and partially conceal the outer head of the gastrocnemius.

The short head may be absent: there may be an additional origin from the ischium or femur; and the long head may send a slip to the gastrocnemius or tendo Achillis (**tensor fasciæ suralis**).

The **semitendinosus** arises, in common with the long head of the biceps, from the lower and inner facet upon the ischial tuberosity (Fig. 285, p. 369). Separating from the common tendon after a course of two or three inches, the muscle forms a long, narrow band which becomes tendinous in the middle third of the thigh. Passing over the inner side of the knee it spreads out and becomes membranous, and is **inserted** (1) into the inner side of the shaft of the tibia just below the internal tuberosity, below the gracilis and behind the sartorius (Fig. 292, p. 374), and (2) into the fascia lata of the leg. A bursa separates it from the sartorius in front, and another, common to it and the gracilis, lies beneath its insertion.

The origin of the muscle is concealed by the gluteus maximus. In the back of the thigh it is superficial to the semimembranosus; and at the inner side of the knee the tendon lies behind that of the gracilis, and also behind the sartorius. It forms one of the inner boundaries of the popliteal space. The belly of the muscle is marked by an oblique septal tendinous intersection about its middle.

The **semimembranosus** arises by a tendon from the upper and outer facet on the ischial tuberosity (Figs. 282, p. 366, and 285, p. 369). In the upper third of the thigh the tendon gives place to a rounded fleshy belly, which, becoming tendinous at the back of the knee, is **inserted** mainly into the horizontal groove on the back of the inner tuberosity of the tibia, and into a triangular area below the hinder end of the groove, and above the insertion of the popliteus (Figs. 292, p. 374, and 299, p. 383). A bursa lies beneath the tendon at its insertion. It has three *additional membranous insertions*: (1) a fascial band extends downwards and inwards to join the posterior border of the internal lateral ligament of the knee-joint; (2) another fascial band extends downwards and outwards, forms the fascia covering the popliteus

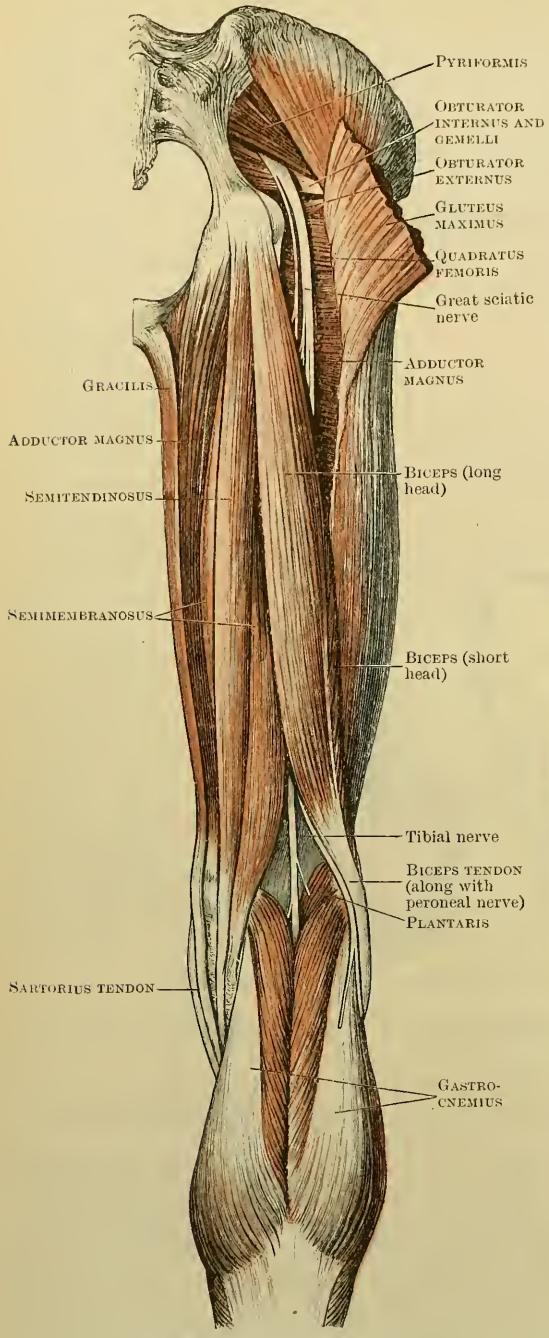


Fig. 291.—The Muscles on the Back of the Thigh.

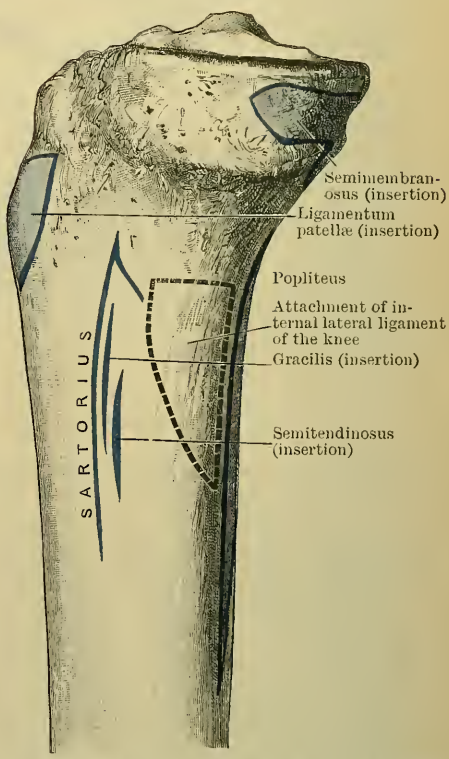


Fig. 292.—Muscle-Attachments to the Inner Side of the Upper Part of the Tibia.

muscle (popliteus fascia), and is attached to the oblique line of the tibia; and (3) a third strong band extends upwards and outwards to the back of the external condyle of the femur, forming the posterior ligament of the knee-joint.

The tendon of origin of the semimembranosus is concealed by the gluteus maximus, and immediately beyond the ischium it is grooved by the common origin of the long head of the biceps and semitendinosus. In the back of the thigh it is

covered by the semitendinosus, and lies upon the adductor magnus and great sciatic nerve. It forms part of the inner boundary of the popliteal space, and conceals the popliteal vessels. Its tendon passes over the inner head of the gastrocnemius on its way to its insertion.

Nerve-Supply of the Muscles of the Thigh and Buttock.

The innervation of the muscles described above is given in the following table:—

Muscles.	Nerves.	Origin.
Pectineus	Anterior crural	L. 2. 3.
Sartorius	Anterior crural	L. 2. 3.
Iliacus	Anterior crural	L. 2. 3. 4.
Psoas	Anterior crural	L. 2. 3. 4.
Quadriceps extensor	Anterior crural	L. 3. 4.
Vastus externus	Anterior crural	L. 3. 4.
Rectus femoris	Anterior crural	L. 3. 4.
Crureus	Anterior crural	L. 3. 4.
Vastus internus	Anterior crural	L. 3. 4.
Tensor fasciæ femoris	Superior gluteal	L. 4. 5. S. 1.
Gluteus minimus	Superior gluteal	L. 4. 5. S. 1.
Gluteus medius	Superior gluteal	L. 4. 5. S. 1.
Gluteus maximus	Inferior gluteal	L. 5. S. 1. 2.
Biceps (short head)	Peroneal	L. 5. S. 1. 2.
Pyriformis	Sacral plexus	S. 1. 2.
Adductor longus	Obturator	L. 2. 3.
Gracilis	Obturator	L. 2. 3. 4.
Adductor brevis	Obturator	L. 3. 4.
Obturator externus	Obturator	L. 3. 4.
Adductor magnus	Obturator	L. 3. 4.
	Nerve to hamstrings	L. 4. 5. S. 1.
Semimembranosus	Nerve to hamstrings	L. 4. 5. S. 1.
Semitendinosus	Nerve to hamstrings	L. 5. S. 1. 2.
Biceps (long head)	Nerve to hamstrings	S. 1. 2. 3.
Quadratus femoris and inferior gemellus	Sacral plexus	L. 4. 5. S. 1.
Superior gemellus and obturator internus	Sacral plexus	S. 1. 2. 3.

Action of the Muscles of the Thigh and Buttock.

Most of the above muscles act on the pelvis and on the hip- and knee-joints. The psoas muscle in addition assists in the movements of the vertebral column (p. 398).

1. **Movements at the Hip-Joint.**—The movements of the thigh at the hip-joint are flexion and extension, adduction and abduction, internal and external rotation. The following table gives the muscles producing these movements:—

a. **Flexion** and **Extension.**	
Sartorius	Gluteus maximus
Iliacus	„ medius
Psoas	„ minimus
Rectus femoris	Biceps
Pectineus	Semitendinosus
Adductor longus	Semimembranosus
Gracilis	Adductor magnus
Obturator externus	

b. **Adduction**	and	**Abduction.**
Pectineus		Tensor fasciæ femoris
Adductor longus		Gluteus medius
„ brevis		Gluteus minimus
„ magnus		Obturator externus
Gracilis		Pyriformis)
Quadratus femoris		Obturator internus) during
Gluteus maximus (lower fibres)		Gemelli) flexion
		Sartorius)
		Gluteus maximus (upper fibres))

c. **Internal Rotation**	and	**External Rotation.**
Tensor fasciæ femoris		Obturator externus
Gluteus medius (anterior fibres)		Gluteus maximus (lower fibres)
„ minimus „ „		Quadratus femoris
		Gluteus medius) (posterior
		„ minimus) fibres)
		Pyriformis) during
		Obturator internus) during
		Gemelli) extension
		Sartorius
		Ilio-psoas
		Pectineus
		Adductor longus
		„ brevis
		„ magnus
		Biceps flexor cruris

2. Movements of the Pelvis on the Thigh.—It is to be noted that the several movements tabulated above refer to the movements of the femur at the hip-joint. The contraction of the same groups of muscles produces similar movements of the pelvis on the femur, exemplified in the various changes in the attitude of the pelvis in relation to the thigh and the vertebral column, which occur in locomotion.

3. Movements at the Knee-Joint.—The movements at the knee-joint are mainly flexion and extension. Flexion is much more powerful than extension. There is also a limited amount of rotation of the tibia. The movements are produced by certain of the muscles described above, associated with certain of the muscles of the leg.

a. **Flexion**	and **Extension.**	*b.* **Rotation inwards**	and **Rotation outwards.**
Sartorius	Quadriceps extensor	Sartorius	Biceps flexor cruris
Gracilis		Gracilis	
Semitendinosus		Semitendinosus	
Semimembranosus		Semimembranosus	
Biceps		Popliteus	
Gastrocnemius			
Plantaris			
Popliteus			

THE FASCIÆ AND MUSCLES OF THE LEG AND FOOT.

FASCIÆ.

The **superficial fascia** of the leg presents no special features except in the sole, where it is greatly thickened by pads of fat, particularly under the tuberosity of the os calcis, and under the balls of the toes. It is closely adherent to the plantar fascia, especially at the roots of the toes.

The **deep fascia** has numerous important attachments about the knee. Posteriorly it forms the popliteal fascia, and is joined by expansions from the tendons of the sartorius, gracilis, semitendinosus, and biceps muscles. In front of the knee it is attached to the patella, the ligamentum patellæ, and the tubercle of

the tibia; laterally it is connected to the tuberosities of the tibia and the head of the fibula, and forms the **lateral patellar ligaments**, broad fascial bands which pass obliquely from the sides of the patella to the tuberosities of the tibia, and are joined by fibres of the vasti muscles. Passing down the leg, the fascia blends over the inner surface of the tibia with the periosteum of the bone. It extends round the outer side of the leg from the anterior to the internal border of the tibia, binding together and giving origin to the muscles, and gaining an attachment to the lower part of the shaft of the fibula. **Two septa** pass from its deep surface; one septum, attached to the anterior border of the fibula, encloses the musculo-cutaneous nerve, and separates the extensor from the peronei muscles. The other septum is attached to the posterior border of the fibula, and separates the peronei from the flexor muscles. From the last-named septum another extends across the back of the leg, forms a partition between the superficial and deep flexor muscles, and encloses the posterior tibial vessels and nerves. It gives rise to a subordinate septum attached to the vertical line of the tibia and the oblique line of the fibula, which separate the tibialis posticus muscle from the flexors of the toes on either side.

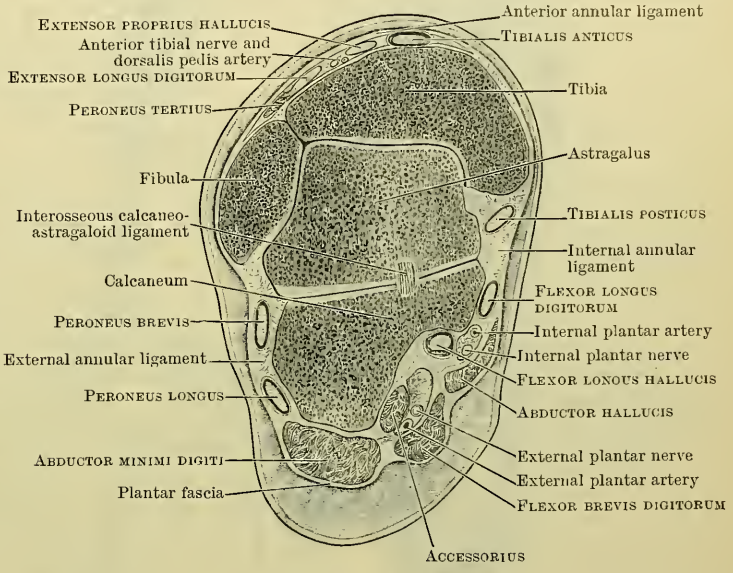


Fig. 293.—Coronal Section through the left Ankle-Joint, Astragalus, and Calcaneum.

At the ankle the deep fascia is strengthened by additional transverse fibres; it is attached to the malleoli and the os calcis, and gives rise to the **annular ligaments.**

The **internal annular ligament** stretches between the internal malleolus and the tuberosity of the os calcis. While it is continuous at its upper border with the general investment of the deep fascia of the leg, it is chiefly formed by the septal layer covering the deep muscles on the back of the leg. It sometimes gives insertion to the plantaris muscle. It is continuous below with the plantar fascia, and gives origin to the abductor hallucis muscle. It is pierced by the calcanean vessels and nerve. Along with the posterior tibial vessels and nerve, the tendons of the tibialis posticus, flexor longus digitorum, and flexor longus hallucis, pass beneath it, each enclosed in a separate synovial sheath.

The **external annular ligament**, much smaller, is a thickened band of the deep fascia stretching between the external malleolus and the os calcis. It binds down the tendons of the peronei, which occupy a space beneath the ligament, lined by a single synovial membrane.

The **anterior annular ligament** is in two parts. An **upper band**, broad and undefined at its upper and lower borders, stretches across the front of the ankle between the two malleoli. This band binds down to the lower end of the tibia the tendons of the tibialis anticus and extensor muscles of the toes. One synovial sheath is found beneath it, surrounding the tendon of the tibialis anticus.

On the dorsum of the foot, where the general covering of deep fascia is much thinner, a special well-defined band stretches over the extensor tendons. This **lower band** of the anterior annular ligament (fundiform or lambdoid ligament) has an attachment externally to the outer border of the greater process of the os calcis. It divides into two bands as it passes inwards over the dorsum of the foot—an

upper part, which joins the upper ligament and is attached to the internal malleolus, and a *lower part*, which passes across the dorsum of the foot, and joins the fascia of the sole at its inner border. Beneath this ligament are three special compartments with separate synovial sacs, one for the tibialis anticus tendon, a second for that of the extensor proprius hallucis, and a third for the extensor longus digitorum and peroneus tertius tendons. There are occasionally other additional bands of the deep fascia passing like the straps of a sandal across the dorsum of the foot.

The **plantar fascia** is of great importance. In the centre of the sole it forms a thick triangular band, attached posteriorly to the tuberosity of the os calcis. It spreads out anteriorly and separates into *five slips*, which are directed forwards to the bases of the toes. These slips as they separate are joined together by ill-defined bands of transverse fibres, which constitute the **superficial transverse metatarsal ligament**. The slip for each toe joins the tissue of the web of the toe and is continuous with the digital sheath. It splits to form a band of fibres directed forwards on each side of the toe to be attached to the sides of the metatarso-phalangeal articulation and the base of the first phalanx.

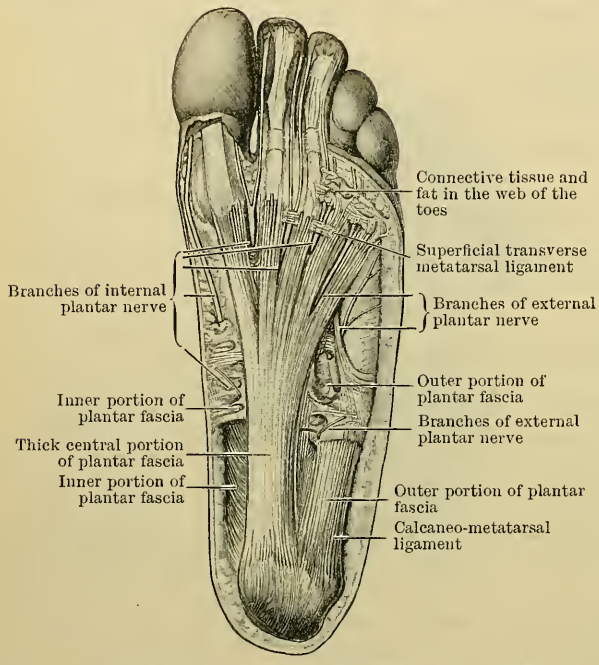


Fig. 294.—The Plantar Fascia and Plantar Cutaneous Nerves.

This central portion of the plantar fascia assists in preserving the arch of the foot, by drawing the toes and the os calcis together.

On each side it is continuous with a much thinner layer which covers the lateral muscles of the sole, and joins the fascia of the dorsum of the foot at each border. It also gives rise to intermuscular septa, which pass upwards on each side of the flexor brevis digitorum, enclosing that muscle in a separate sheath, and giving investments on either side to the abductor muscles of the great and little toes. At the outer border of the foot the **calcaneo-metatarsal ligament**, a thickened band of the fascia, connects the tuberosity of the os calcis with the base of the fifth metatarsal bone.

The **digital sheaths**, though smaller, are the same in arrangement as those of the fingers. **Vaginal ligaments** are present in relation to the first and second phalanges.

THE MUSCLES OF THE LEG AND FOOT.

The muscles of the leg and foot are divisible into three series: (1) the extensor muscles on the front of the leg and dorsum of the foot; (2) the peronei on the outer side of the leg; and (3) the flexor muscles on the back of the leg and in the sole of the foot.

The Muscles on the Front of the Leg and Dorsum of the Foot.

The muscles on the front of the leg and dorsum of the foot include two groups: (1) on the front of the leg, the tibialis anticus, long extensors of the toes and peroneus tertius; and (2) on the dorsum of the foot, the extensor brevis digitorum.

The **tibialis anticus** (m. tibialis anterior) arises by fleshy fibres from the outer

tuberosity and the upper two-thirds of the outer surface of the shaft of the tibia, from the interosseous membrane, from the fascia over it, and from an intermuscular septum externally. The muscle ends in a strong tendon which passes over the dorsum of the foot, to be **inserted** into a facet on the anterior and inferior part of the inner surface of the internal cuneiform and the adjacent inner side of the base of the first metatarsal bone (Fig. 295, p. 379).

The muscle is superficially placed along the outer side and front of the tibia,

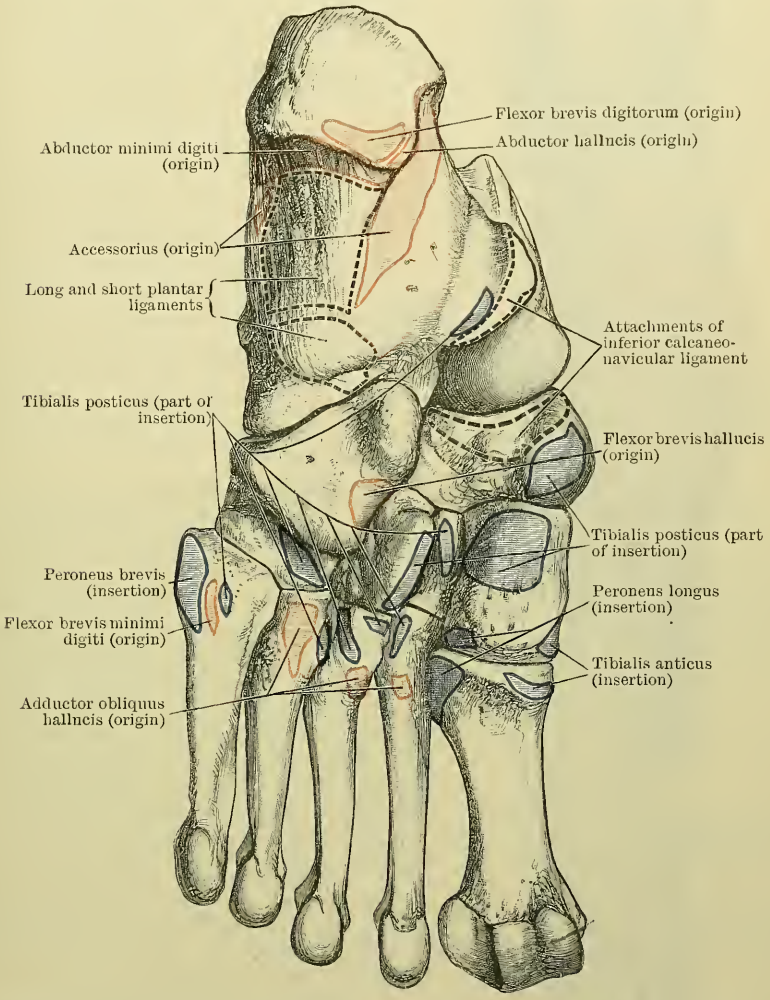


FIG. 295.—MUSCLE-ATTACHMENTS TO TARSUS AND METATARSUS (Plantar Aspect).

internal to the long extensors of the toes and the anterior tibial vessels and nerve. Its tendon occupies special compartments beneath both upper and lower parts of the anterior annular ligament, enclosed in a separate, single, synovial sac.

The **tibio-fascialis anticus** is a separated portion of the muscle occasionally present, inserted into the fascia on the dorsum of the foot.

The **extensor longus digitorum** arises by fleshy fibres from the outer side of the external tuberosity of the tibia, from the upper two-thirds or more of the anterior surface of the shaft of the fibula, from the fascia over it, and from intermuscular septa on either side. It gives rise to a tendon which passes beneath the anterior annular ligament, and in front of the ankle subdivides into four tendons, **inserted** into the four outer toes, exactly in the same way as the corresponding tendons in the hand (see p. 347). They form membranous expansions on the

dorsum of the first phalanx, joined by the tendons of the extensor brevis digitorum, lumbricales, and interossei, which separate into one central and two lateral slips, attached respectively to the middle and terminal phalanges.

The muscle is superficial, and is placed external to the tibialis anticus and extensor proprius hallucis, and internal to the peronei muscles. The musculo-cutaneous nerve is on its outer side. It conceals the anterior tibial vessels and nerve. The tendon occupies a separate compartment along with the peroneus tertius beneath the lower part of the anterior annular ligament, invested by a special synovial membrane.

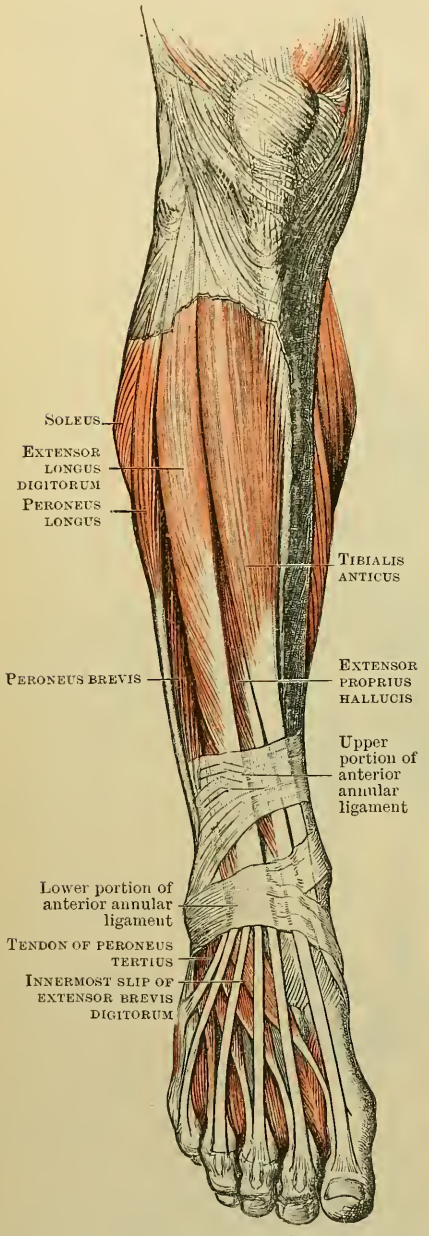


Fig. 296.—Muscles of the Front of the Right Leg and Dorsum of the Foot.

The **peroneus tertius** is a separated portion of the extensor longus digitorum. It is an essentially human muscle. It **arises** (inseparably from the extensor longus digitorum) from the lower part of the anterior surface of the fibula, from the interosseous membrane, and from the intermuscular septum external to it. The tendon of the muscle is **inserted** into the dorsal aspect of the base of the fifth metatarsal bone. It accompanies the extensor longus digitorum beneath the anterior annular ligament, and lies external to the tendons of that muscle on the dorsum of the foot.

The **extensor proprius hallucis muscle** (m. extensor hallucis longus) **arises** by fleshy fibres from the front of the fibula in its middle three-fifths, internal to the origin of the extensor longus digitorum, and for a corresponding extent from the interosseous membrane. Its tendon passes over the dorsum of the foot, to be **inserted** into the base of the terminal phalanx of the great toe. In the leg the muscle is deeply placed between the tibialis anticus and extensor longus digitorum. It conceals the anterior tibial vessels and nerve, and crosses the termination of the anterior tibial artery in front of the ankle-joint. It is invested by a special synovial sac as it lies beneath the lower part of the anterior annular ligament. On the dorsum of the foot the tendon is placed on the inner side of the dorsalis pedis artery.

The **extensor longus primi internodii** and **extensor ossis metatarsi hallucis** are occasional separate slips of this muscle inserted into the bones of the great toe.

The **extensor brevis digitorum** **arises** on the dorsum of the foot by short tendinous and fleshy fibres from a special impression on the upper surface of the greater process of the os calcis, and from the deep surface of the lower band of the anterior annular ligament.

It usually gives rise to four fleshy bellies, from which narrow tendons are directed forwards and inwards, to be **inserted** into the four inner toes. The three outer tendons join those of the long extensor muscle to form the membranous expansions on the dorsum of the toes. The *innermost tendon* is inserted separately into the base of the first phalanx of the great toe.

The muscle is covered by the lower band of the anterior annular ligament, and by the tendons of the extensor longus digitorum and peroneus tertius; the slip of the muscle passing to the great toe crosses over the dorsalis pedis artery.

The Muscles on the Outer Side of the Leg.

The muscles on the outer side of the leg comprise the peronei—longus and brevis.

The **peroneus longus** arises by fleshy fibres from the head and the upper two-thirds of the outer surface of the shaft of the fibula, from intermuscular septa on either side, and from the fascia over it. It forms a stout tendon, which hooks round the external malleolus, crosses the outer side of the os calcis, and passing through the groove on the cuboid bone, is directed across the sole of the foot to be **inserted** into the outer sides of the internal cuneiform and the base of the first metatarsal bones (Fig. 295, p. 379). The muscle is placed superficially in the leg, and is separated by intermuscular septa from the extensor longus digitorum and peroneus brevis in front, and the soleus and flexor longus hallucis behind. It partially conceals the peroneus brevis, along with which it passes beneath the external annular ligament, invested by a common synovial sheath. As it enters the sole of the foot a *fibro-cartilage* is formed in the tendon, which plays over a smooth tubercle on the cuboid bone, a bursa intervening. In its passage across the foot the tendon is enclosed in a fibrous sheath derived from the inferior calcaneo-cuboid ligaments and the tibialis posticus tendon, and is concealed by the first three layers of the muscles of the sole.

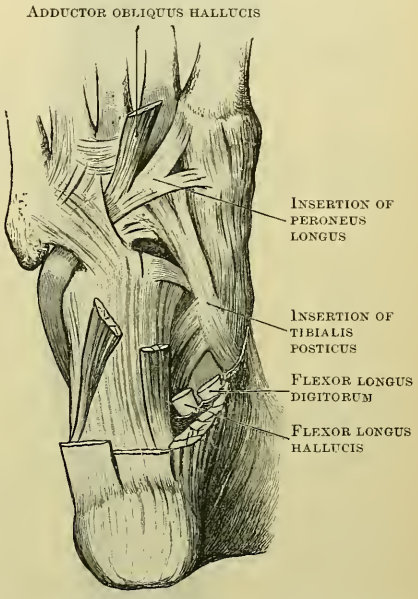


Fig. 297.—The Insertions of the Peroneus Longus and Tibialis Posticus Muscles in the Sole of the Right Foot.

The **peroneus brevis** arises by fleshy fibres from the lower two-thirds of the outer surface of the shaft of the fibula, and from an intermuscular septum along its anterior border. Its tendon passes over the back of the external malleolus and the outer side of the os calcis, to be **inserted** into the tubercle and dorsal surface of the base of the fifth metatarsal bone. In the leg the peroneus brevis lies behind the extensor longus digitorum and peroneus tertius, and in front of the peroneus longus, which partially overlaps it. The tendon lies directly behind the external malleolus beneath the external annular ligament, invested by a synovial sheath common to it and the peroneus longus.

The peroneus longus and brevis may be fused together, or additional slips may be present, as **peroneus accessorius, peroneus quinti digiti, peroneo-calcaneus externus,** and **peroneo-cuboideus.**

The Muscles on the Back of the Leg.

The muscles on the back of the leg are divisible into two layers: (1) a **superficial set**, consisting of the gastrocnemius and soleus (the so-called triceps muscle of the leg), and the plantaris; and (2) a **deep set**, consisting of the popliteus, flexor longus digitorum, tibialis posticus, and flexor longus hallucis.

The **gastrocnemius** arises by *two heads*, inner and outer, by means of strong tendons which are prolonged over the surface of the muscle. The outer head arises from an impression on the upper and posterior part of the outer surface of the external condyle, and from the lower end of the external supra-condyloid ridge; while the inner head arises from a prominent rough mark on the popliteal space of the femur above the internal condyle and from the surface between that and the

adductor tubercle. Each head has an additional origin from the back of the capsule of the knee-joint. A bursa lies beneath each tendon of origin. Each fleshy belly of the muscle is **inserted** into a broad membranous tendon, prolonged upwards on its deep surface for some distance. The inner head is the larger.

The **tendo Achillis** is formed by the union of the two membranous insertions of the bellies of the gastrocnemius. Prolonged upwards beneath the separate bellies, the tendon forms a broad membranous band connecting together the lower parts of the two bellies. Narrowing gradually, and becoming thicker in the lower half of the leg, the tendon is finally **inserted** into the intermediate surface on the posterior aspect of the os calcis. A bursa lies beneath the tendon at its insertion. The tendo Achillis also affords insertion to the soleus and (sometimes) the plantaris muscles.

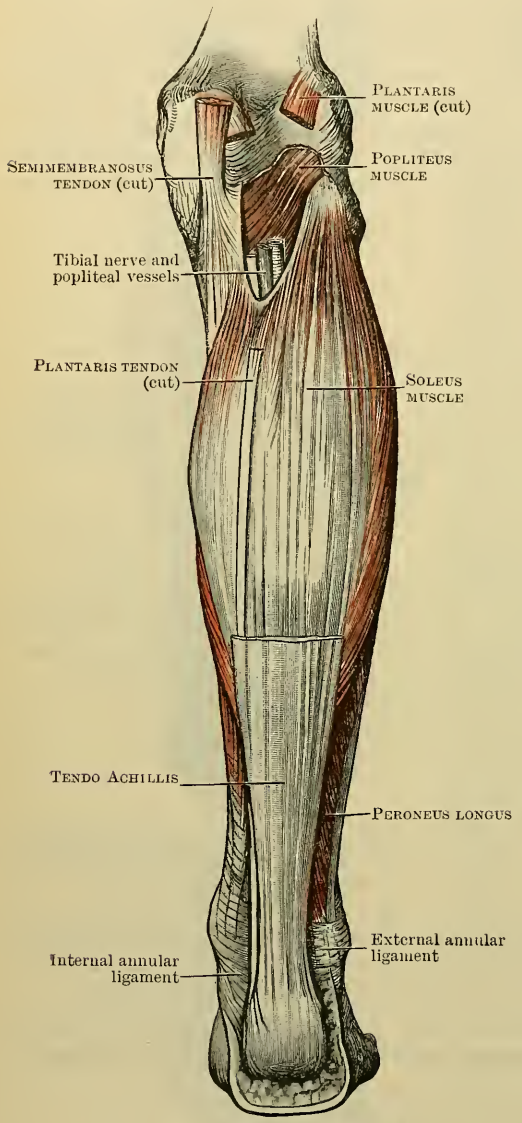


Fig. 298.—The Soleus Muscle.

The gastrocnemius is superficial except at its origin. The inner head is concealed by the semitendinosus and semimembranosus muscles, and partially covers the popliteal vessels and the tibial nerve in the lower part of their course. It forms part of the inner boundary of the popliteal space. The outer head is concealed partially by the biceps tendon and the peroneal nerve, and covers the plantaris muscle, the popliteal vessels, and the tibial nerve. It forms part of the outer boundary of the popliteal space. The two bellies are for the most part in close contact, the external saphenous vein occupying the interval between them. The tendo Achillis in the lower half of the leg partially conceals the soleus and the deeper muscles. The plantaris tendon lies along its inner border.

The **plantaris** arises by fleshy fibres from the external supra-condyloid ridge of the femur for about an inch at its lower end, from the adjacent part of the popliteal space of the femur, and from the posterior ligament of the knee-joint. It forms a narrow fleshy slip which ends in a tendon extending down the back of the leg, to be **inserted** into the inner side of the tuberosity of the os calcis, or the tendo Achillis, or the internal annular ligament. The tendon of the muscle is capable of considerable lateral extension. The plantaris lies between the outer head of the gastrocnemius and the soleus, and crosses the popliteal vessels and the tibial nerve. In the lower half of the leg its tendon lies along the inner border of the tendo Achillis. The muscle is not always present.

The **soleus** has a triple **origin** by means of short tendinous and fleshy fibres: (1) from the posterior surface of the head and the shaft of the fibula in its upper third; (2) from a fibrous arch stretching over the popliteal vessels and tibial nerve between the tibia and fibula; and (3) from the oblique line and middle third of

the inner border of the tibia (Fig. 299, p. 383). From this origin the upper muscular fibres are directed downwards to join a tendon placed on the superficial aspect of the muscle, which is **inserted** into the tendo Achillis; the lower fibres are inserted directly into the tendo Achillis to within one or two inches of the os calcis.

The muscle is concealed by the gastrocnemius, plantaris, and tendo Achillis in nearly its whole extent. It is partially superficial on each side of the gastrocnemius

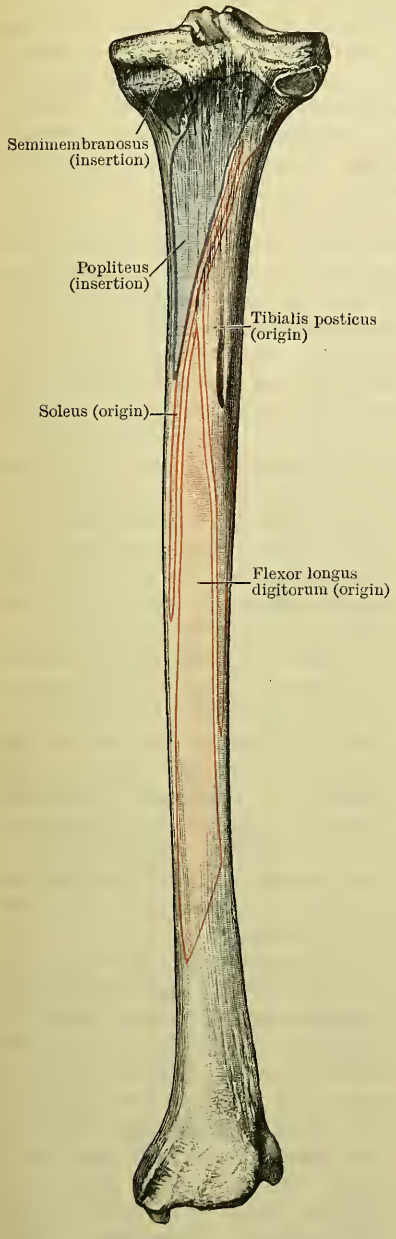


Fig. 299.—Muscle-Attachments to the Posterior Surface of the Tibia.

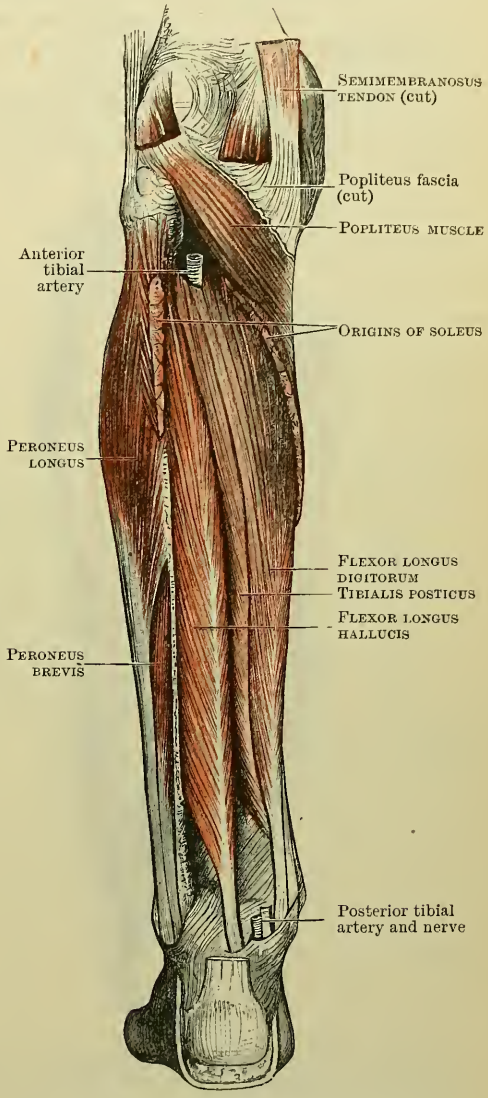


Fig. 300.—The Deep Muscles on the Back of the Left Leg.

and tendo Achillis. The muscle covers the tibialis posticus and the flexor muscles of the toes as well as the posterior tibial vessels and nerve.

The **deep muscles** of the back of the leg comprise the popliteus, the long flexors of the toes, and the tibialis posticus.

The **popliteus** is deeply placed behind the knee. It arises by a stout tendon from a rough impression in front of a groove on the outer aspect of the external

condyle of the femur. This tendon passes between the external semilunar cartilage and the capsule of the knee-joint, and pierces the posterior ligament, from which it takes an additional fleshy origin. A bursa is placed beneath the tendon, which communicates usually with the synovial cavity of the knee-joint. The muscle is **inserted** by fleshy fibres (1) into a triangular surface on the back of the tibia above the oblique line (except a small area below the fibular facet) (Fig. 299, p. 383), and (2) into the fascia over it (the popliteus fascia, derived from the tendon of the semimembranosus muscle). The popliteus is covered at its origin by the capsule of the knee-joint. Posteriorly it is concealed by the gastrocnemius and plantaris muscles, and by the popliteal vessels and the tibial nerve. Its lower border corresponds to the point of bifurcation of the popliteal artery and the origin of the soleus muscle.

The **popliteus minor** is a small occasional muscle attached to the popliteal space of the femur and the posterior ligament of the knee-joint.

The **flexor longus digitorum** occupies both the back of the leg and the sole of the foot. Its **origin** is by fleshy fibres from the posterior surface of the shaft of the tibia in its middle three-fifths, below the oblique line, and internal to the vertical line and the origin of the tibialis posticus, from the fascia over it, and from an intermuscular septum on each side (Fig. 299, p. 383). Its tendon, after passing beneath the internal annular ligament, enters the sole of the foot, and divides into four subordinate tendons, which are **inserted** into the four outer toes in precisely the same manner as the flexor profundus digitorum is inserted in the hand. Each tendon enters the digital sheath of the toe, perforates the tendon of the flexor brevis digitorum, and is inserted into the base of the terminal phalanx. **Ligamenta accessoria** (**longa** and **brevia**) are present as in the hand. Associated with this muscle in the sole of the foot are the lumbricales and accessorius muscles.

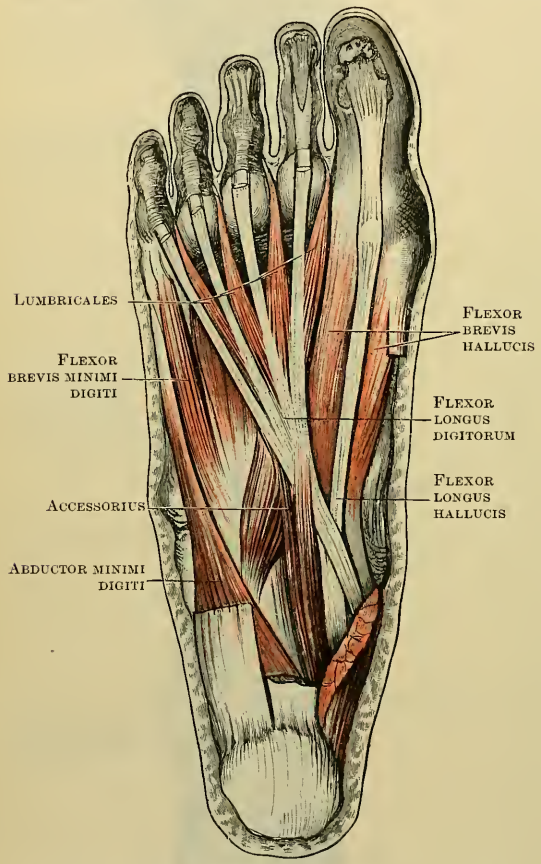


FIG. 301.—THE MUSCLES OF THE RIGHT FOOT (after removal of the first layer).

The **lumbricales** are four small muscles **arising** in association with the tendons of the flexor profundus digitorum in the sole. The *first muscle* arises by a single origin from the tibial side of the tendon of the flexor longus digitorum for the second toe; the *other three* arise by two heads from the adjacent sides of all four tendons. Each muscle is **inserted** into the dorsal expansion of the extensor tendon, the metatarso-phalangeal capsule, and the base of the first phalanx, precisely as in the case of the lumbrical muscles of the hand. Each muscle passes forwards on the tibial side of the corresponding toe, superficial to the transverse metatarsal ligament.

The **flexor accessorius muscle** (m. quadratus plantæ) **arises** by two heads: (1) the outer tendinous head springs from the outer border of the inferior surface of the os calcis and from the outer border of the long plantar ligament; (2) the inner head, which is fleshy, arises from the concave inner surface of the os calcis in its whole extent, and from the inner border of the long plantar ligament (Fig. 295,

p. 379). The long plantar ligament separates the two origins. The two heads unite to form a flattened band, which is **inserted** into the upper aspect of the tendons of the flexor longus digitorum, and usually into those destined for the second, third, and fourth toes.

In the leg the flexor longus digitorum lies at first internal to the tibialis posticus, and is partially concealed by the soleus and tendo Achillis. Its tendon crosses over the tibialis posticus above the ankle-joint, passes beneath the internal annular ligament, invested by a special synovial sheath, and below the ligament crosses the plantar or superficial surface of the tendon of the flexor longus hallucis. As it passes over this tendon it receives from it a special band of fibres, usually associated with the tendons for the second and third toes.

In the sole of the foot the tendons of the flexor longus digitorum, along with the lumbricales and accessorius, and the flexor longus hallucis muscles, constitute the second layer of muscles of the sole. They are placed between the abductors of the great and little toes and the flexor brevis digitorum on the one hand, and the flexor brevis and adductors of the great toe on the other.

The **flexor longus hallucis** **arises** by fleshy fibres on the back of the leg from the lower two-thirds of the posterior surface of the shaft of the fibula, from the fascia over it, and from intermuscular septa on either side. Its tendon passes beneath the internal annular ligament enclosed in a special synovial sheath, and after grooving the back of the lower end of the tibia, the astragalus, and the under surface of the sustentaculum tali of the os calcis, it is directed forwards in the sole of the foot, to be **inserted** into the base of the terminal phalanx of the great toe.

The muscle is partially concealed in the leg by the soleus and tendo Achillis. It lies at its origin between the tibialis posticus and the peronei muscles, separated from the former by the peroneal artery. In the foot, concealed by the abductor hallucis, it crosses over the deep aspect of the tendon of the flexor longus digitorum, to which it is connected by a strong fibrous band destined for the tendons for the second and third toes. At the root of the great toe the tendon occupies the interval between the insertions of the flexor brevis hallucis.

The **tibialis posticus muscle** (m. tibialis posterior) has a fourfold fleshy **origin** in the leg. It arises (1) from the upper four-fifths of the shaft of the fibula between the oblique line and the interosseous border; (2) from the lower part of the outer tuberosity of the tibia and from the upper two-thirds of the shaft of the bone below the oblique line and between the vertical line and the interosseous border (Fig. 299, p. 383); (3) from the interosseous membrane; and (4) from the fascia over it and the septa on either side. The muscle gives rise to a strong tendon which passes beneath the internal annular ligament, invested by a special synovial sheath, and grooves the back of the internal malleolus, on its way to the inner border of the foot. The tendon then spreads out and is **inserted** by three bands into (1) the tubercle of the navicular bone and the plantar surfaces of the internal and middle cuneiform bones, (2) the plantar aspects of the second, third, fourth, and sometimes the fifth metatarsal bones, the middle and external cuneiform bones, and the groove on the cuboid, and (3) by a recurrent slip into the inner border of the sustentaculum tali of the os calcis from which a fibrous expansion passes outwards to join the inner border of the short plantar ligament (Fig. 302, p. 386).

In the leg the tibialis posticus is concealed, as it lies on the interosseous membrane between the tibia and fibula, by the superficial muscles and the posterior tibial vessels and nerve. It lies between the flexor longus hallucis and flexor longus digitorum, and is crossed by the tendon of the latter muscle just above the ankle. Just below the knee between its tibial and fibular origins is an angular space through which the anterior tibial vessels pass. In the foot its tendon is covered by the long flexor tendons and by the short flexor muscles of the great toe. The tendon is in contact with the inferior calcaneo-navicular ligament in the interval between the sustentaculum tali and the navicular bone.

The **peroneo-calcaneus** muscle, when present, **arises** from the fibula, and is **inserted** into the os calcis.

The Muscles in the Sole of the Foot.

The muscles in the sole of the foot are divisible into four layers placed beneath the plantar fascia.

First layer: Abductor hallucis, flexor brevis digitorum, abductor minimi digiti.

Second layer: Lumbricales and accessorius, together with the tendons of the flexor longus hallucis and flexor longus digitorum.

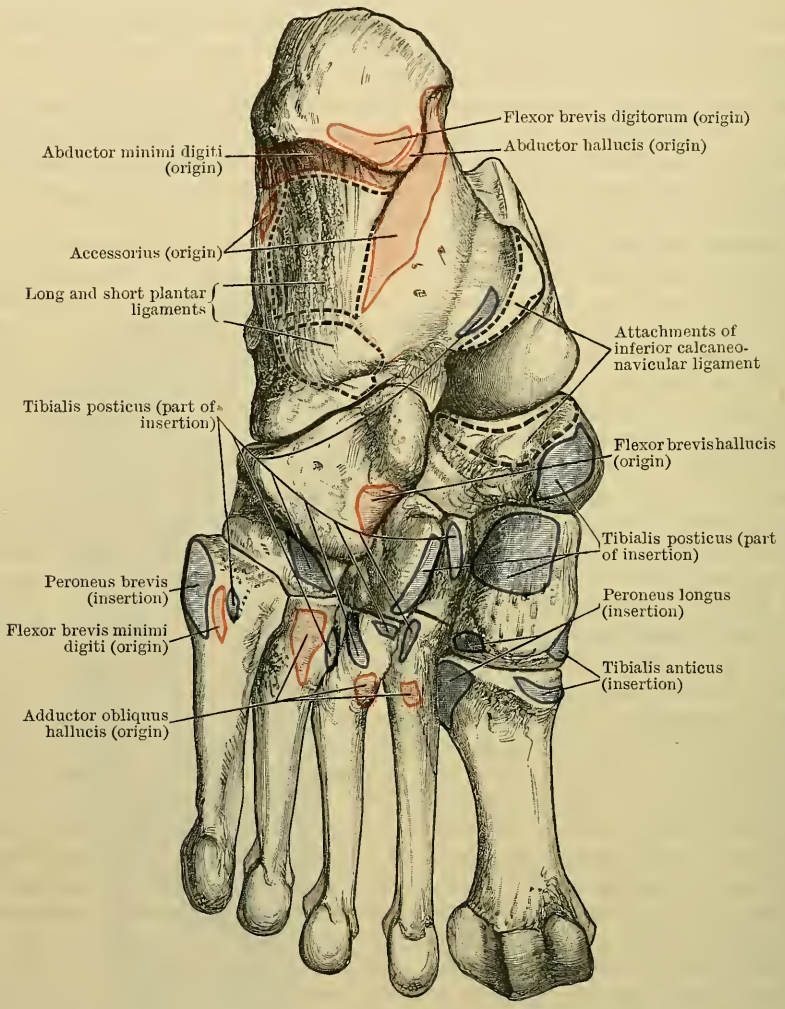


Fig. 302.—Muscle-Attachments to Tarsus and Metatarsus (Plantar Aspect).

Third layer: Flexor brevis hallucis, adductors of the great toe, and flexor brevis minimi digiti.

Fourth layer: Interossei (plantar and dorsal).

The **abductor hallucis** has a double **origin**, (1) by a short tendon from the inner side of the greater tubercle on the tuberosity of the os calcis (Fig. 302, p. 386), and (2) by fleshy fibres from the internal annular ligament, the plantar fascia which covers it, and the intermuscular septum between it and the flexor brevis digitorum. Lying superficially along the inner border of the sole, its tendon is **inserted**, along with part of the flexor brevis hallucis, into the inner side of the posterior end of the first phalanx of the great toe. The muscle lies beneath the plantar fascia, internal to the flexor brevis digitorum, and conceals the plantar vessels and nerves, and near its origin the long flexor tendons.

The **flexor brevis digitorum** has likewise a double **origin**: (1) by a short

tendon from the fore-part of the greater tubercle of the tuberosity of the os calcis (Fig. 302, p. 386), and (2) by fleshy fibres from the thick central part of the plantar fascia which covers it, and from the intermuscular septa on either side. Passing forwards, it gives rise to four slender tendons, which are **inserted** into the second phalanges of the four outer toes, after having been perforated, just as in the case of the tendons of the flexor sublimis digitorum of the hand, by the long flexor tendons. Placed in the centre of the sole beneath the plantar fascia, and between the abductor hallucis and abductor minimi digiti muscles, the muscle conceals the second layer of muscles and the external plantar vessels and nerve.

The **abductor minimi digiti** (m. abductor digiti quinti) has also a double **origin**: (1) by fleshy and tendinous fibres from the fore-part of both tubercles on the tuberosity of the os calcis, partly concealed by the flexor brevis digitorum (Fig. 302, p. 386), and (2) by fleshy fibres from the outer portion of the plantar

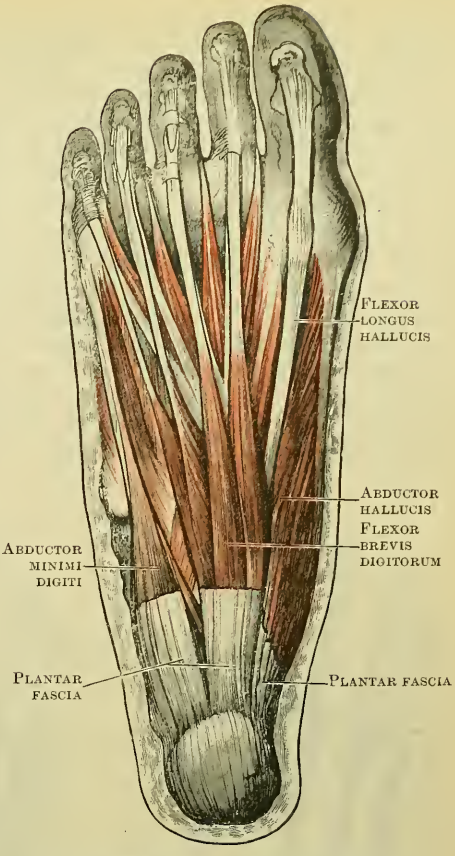


Fig. 303.—The Muscles of the Right Foot (after removal of the plantar fascia).

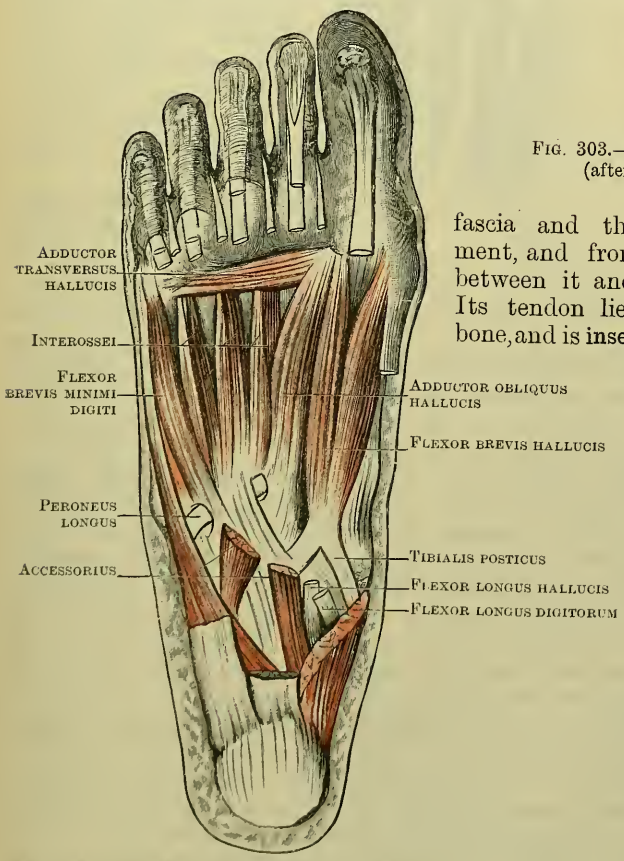


Fig. 304.—The Muscles of the Right Foot (after removal of the second layer).

fascia and the calcaneo-metatarsal ligament, and from the intermuscular septum between it and the flexor brevis digitorum. Its tendon lies along the fifth metatarsal bone, and is **inserted** by a tendon into the outer side of the posterior end of the first phalanx of the little toe. The outermost fibres usually obtain an additional insertion into the outer side of the plantar surface of the fifth metatarsal bone. It lies on the outer side of the flexor brevis digitorum, and partially conceals the flexor brevis minimi digiti.

The tendons of the long flexors of the toes, the **lumbricales** and **accessorius muscles**, constituting the **second layer of muscles**, have already been described. Lying beneath the abductor hallucis and the flexor brevis digitorum, and separated from them by the

plantar vessels and nerves, they occupy the hollow of the tarsus and the space between the first and fifth metatarsal bones; their deep surfaces are in contact with the adductors of the great toe and the interossei muscles.

The **flexor brevis hallucis** arises by tendinous fibres (1) from the inner part of the under surface of the cuboid bone (Fig. 302, p. 386), and (2) from the tendon of the tibialis posticus. Directed forwards over the first metatarsal bone, the muscle separates into two parts, between which is the tendon of the flexor longus hallucis. Each portion gives rise to a tendon which is **inserted** into the corresponding side of the base of the first phalanx of the great toe; in each tendon, under the metatarso-phalangeal articulation, a sesamoid bone is developed. The inner tendon is united with the insertion of the abductor, the outer tendon with the insertions of the adductor muscles of the great toe.

The **adductor obliquus hallucis** arises by fleshy and short tendinous fibres (1) from the sheath of the peroneus longus, and (2) from the plantar surfaces of the posterior extremities of the second, third, and fourth metatarsal bones (Fig. 302, p. 386). Occupying the hollow of the foot, on a deeper plane than the long flexor tendons and lumbricales, and separated from the interossei by the plantar arch, it is placed on the outer side of the flexor brevis hallucis, and is directed obliquely inwards and forwards, to be **inserted** on the outer side of the base of the first phalanx of the great toe between and along with the flexor brevis and adductor transversus hallucis. The muscle forms one side of a triangular space in the sole through which the external plantar vessels and nerve pass.

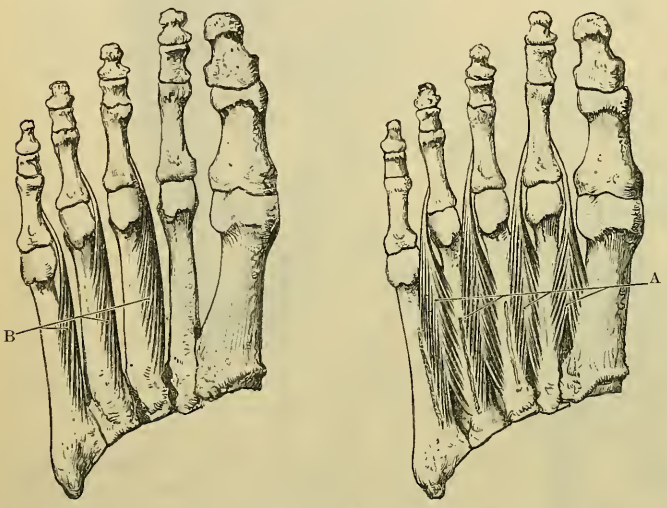


Fig. 305.—Interosseous Muscles of the Foot.

A, Dorsal muscles (plantar aspect); B, Plantar muscles of the right foot.

The **adductor transversus hallucis** arises from (1) the capsules of the outer four metatarso-phalangeal articulations and (2) the transverse metatarsal ligament. Directed transversely inwards, under cover of the flexor tendons and lumbricales, the muscle is **inserted**, along with the adductor obliquus (from which it is separated by an angular interval), into the outer side of the base of the first phalanx of the great toe.

The **flexor brevis minimi digiti** (m. flexor brevis digiti quinti) arises from (1) the sheath of the peroneus longus, and (2) the base of the fifth metatarsal bone (Fig. 302, p. 386). Partially concealed by the abductor minimi digiti, the muscle passes along the fifth metatarsal bone, to be **inserted**, in common with that muscle, into the outer side of the base of the first phalanx of the little toe.

The **interossei muscles** of the foot resemble those of the hand except in one respect. In the hand the line of action of the muscles is the middle line of the middle finger. In the foot the *second toe* is the digit round which the muscles are grouped, and their attachments and their actions differ accordingly.

There are four dorsal and three plantar muscles, which occupy together the four interosseous spaces, and project into the hollow of the foot.

The **four dorsal muscles**, one in each interosseous space, arise by two heads each from the shafts of the metatarsal bones. Each gives rise to a tendon, which, after passing dorsal to the transverse metatarsal ligament, is **inserted** on the dorsum of the foot into the side of the first phalanx, the metatarso-phalangeal capsule, and the dorsal expansion of the extensor tendon. The *first* and *second muscles* are inserted

into the second toe on the tibial and fibular sides respectively. The *third* and *fourth muscles* are inserted into the third and fourth toes on their fibular sides.

The **three plantar muscles** occupy the three outer interosseous spaces. Each **arises** by a single head from the tibial side of the third, fourth, and fifth metatarsal bones respectively. Each ends in a tendon which passes dorsal to the transverse metatarsal ligament, and is **inserted**, in the same manner as the dorsal muscles, into the third, fourth, and fifth toes on their tibial side.

Nerve-Supply of the Muscles of the Leg and Foot.

Muscles.	Nerves.	Origin.
Tibialis anticus	anterior tibial	L. 4. 5. S. 1.
Extensor proprius hallucis	anterior tibial	L. 4. 5. S. 1.
Extensor longus digitorum	anterior tibial	L. 4. 5. S. 1.
Peroneus tertius	anterior tibial	L. 4. 5. S. 1.
Peroneus longus	musculo-cutaneous	L. 4. 5. S. 1.
Peroneus brevis	musculo-cutaneous	L. 4. 5. S. 1.
Extensor brevis digitorum	anterior tibial	L. 4. 5. S. 1.
Plantaris	tibial	L. 4. 5. S. 1.
Popliteus	tibial	L. 4. 5. S. 1.
Gastrocnemius	tibial	S. 1. 2.
Soleus	tibial	S. 1. 2.
Soleus	posterior tibial	L. 5. S. 1. 2.
Flexor longus digitorum	posterior tibial	L. 5. S. 1.
Tibialis posticus	posterior tibial	L. 5. S. 1.
Flexor longus hallucis	posterior tibial	L. 5. S. 1. 2.
Abductor hallucis	internal plantar	L. 4. 5. S. 1.
Flexor brevis digitorum	internal plantar	L. 4. 5. S. 1.
Flexor brevis hallucis	internal plantar	L. 4. 5. S. 1.
First lumbricalis	internal plantar	L. 4. 5. S. 1.
Second, third, and fourth lumbricales	external plantar	S. 1. 2.
Flexor accessorius	external plantar	S. 1. 2.
Adductores hallucis	external plantar	S. 1. 2.
Interossei	external plantar	S. 1. 2.
Flexor brevis minimi digiti	external plantar	S. 1. 2.
Abductor minimi digiti	external plantar	S. 1. 2.

Action of the Muscles of the Leg and Foot.

The muscles of the leg and foot act chiefly in the movements of the ankle-joint (assisted by movements of the inter-tarsal joints); of the metatarso-phalangeal joints (assisted by movements of the tarso-metatarsal and inter-metatarsal joints); and of the inter-phalangeal joints of the several toes.

I. Tibio-Fibular Articulations.—The upper tibio-fibular articulation is only capable of slight gliding movement, occasioned by the action of the biceps and popliteus and the muscles arising from the fibula.

II. Movements at the Ankle-Joint.—The movements at the ankle-joint are movements of flexion and extension of the foot on the leg, along with inversion and eversion (only during extension). These movements are produced at the ankle, aided by movements in the inter-tarsal joints, and are occasioned by the following muscles:—

a. Flexion.	Extension.	*b.* Inversion.	Eversion.
Tibialis anticus	Gastrocnemius	Tibialis anticus	Peroneus tertius
Extensor communis digitorum	Plantaris		Peroneus longus
Extensor proprius hallucis	Soleus	Tibialis posticus	Peroneus brevis
Peroneus tertius	Tibialis posticus		
	Peroneus longus		
	Peroneus brevis		
	Flexor longus digitorum		
	Flexor longus hallucis		

III. Movements of the Toes.—*A.* **At the Metatarso-Phalangeal Joints** (assisted by movements at the tarso-metatarsal and inter-metatarsal joints).—These movements are flexion and extension, abduction and adduction (in a line corresponding to the axis of the second toe).

a. Flexion.	Extension.
Flexor longus digitorum	Extensor longus digitorum
Accessorius	
Lumbricales	Extensor brevis digitorum
Flexor longus hallucis	
Flexor brevis hallucis	Extensor proprius hallucis
Flexor brevis digitorum	
Flexor brevis minimi digiti	
Interossei	

b. Abduction.	Adduction.
(*From and to the middle line of the second toe.*)	
Abductor hallucis	Adductores hallucis
Dorsal interossei	Plantar interossei
Abductor minimi digiti	

B. **At the inter-phalangeal joints** the movements are limited to flexion and extension.

Flexion.	Extension.	
Flexor brevis digitorum (*acting on the first joint*)	Extensor longus digitorum	(*acting on both joints*)
Flexor longus digitorum (*acting on both joints*)	Extensor brevis digitorum	
Flexor longus hallucis (*acting on the hallux*)	Interossei	
	Lumbricales	
	Extensor proprius hallucis	

Movements of the Lower Limb generally.

The characteristic features of the lower limb are stability and strength, and its muscles and joints are both subservient to the functions of transmission of weight and of locomotion. In the standing position the centre of gravity of the trunk falls between the heads of the femora, and is located about the middle of the body of the last lumbar vertebra. It is transmitted through the bones of the lower limb to the arch of the foot, where the astragalus distributes it backwards through the os calcis to the heel, and forwards through the tarsus and metatarsus to the balls of the toes.

Locomotion.—The three chief means of progression are walking, running, and leaping. In **walking**, the body and its centre of gravity are inclined forwards, the trunk oscillates from side to side as it is supported alternately by each foot, the arms swing alternately with the corresponding leg, and one foot is always on the ground. The act of progression is performed by the leg, aided in two ways by gravity. The movements of the leg are as follows: At the beginning of a step, one leg, so to speak, "shoves off;" the heel is raised and the limb is extended. By the action of the muscles flexing the hip and knee-joint, and extending the ankle-joint and toes, this limb is raised from the ground sufficiently to clear it, and passes forwards by the action of gravity, aided by the force given to the movement by the extensor muscles. After passing the line of the centre of gravity the flexion of the joints ceases, the muscles relax, and the limb gradually returns to the ground. The other limb then passes through the same cycle, the weight of the body now resting on the limb which is in contact with the ground. As the foot reaches the ground it, as it were, rolls over it; the heel touches it first, then the sole, and lastly, as the foot leaves the ground again, only the toes. In **running**, the previous events are all exaggerated. The time of the event is diminished, while the force and distance are increased. Both feet are off the ground at one time; the action of flexors and extensors alternately is much more powerful, so that on the one hand the knees are drawn upwards to a greater extent in the forward movement, and not the whole foot, but only the toes reach the ground in the extension of the limb. The attempt is made to bring the foot to the ground in front of the line of the centre of gravity. At the same time the trunk is sloped forwards much more than in walking. In **leaping**, the actions of the limbs are still more exaggerated. The movements of flexion of the limb are still more marked, and the foot reaches the ground still farther in front of the line of the centre of gravity.

AXIAL MUSCLES.

THE FASCIÆ AND MUSCLES OF THE BACK.

THE FASCIÆ OF THE BACK.

The general fascial investments of the back have been described along with the superficial muscles associated with the shoulder-girdle (p. 318). The latissimus dorsi muscle has been described as arising in large part from the **vertebral aponeurosis.** This is a strong fibrous lamina which conceals the erector spinæ muscle. In the loin it extends from the spines of the lumbar vertebræ outwards to the interval between the last rib and the iliac crest, where it is concerned in forming the **lumbar fascia.** Below the loin the vertebral aponeurosis is attached to the iliac crest, and more internally blends with the subjacent tendinous origin of the erector spinæ. The fascia can be followed upwards over the erector spinæ in the region of the thorax, where it is attached externally to the ribs and is continuous with the intercostal aponeuroses. In the lower part of the thorax it is replaced by muscular slips—the serratus posticus inferior; in the upper part of the thorax it passes beneath the serratus posticus superior and blends with the deep cervical fascia.

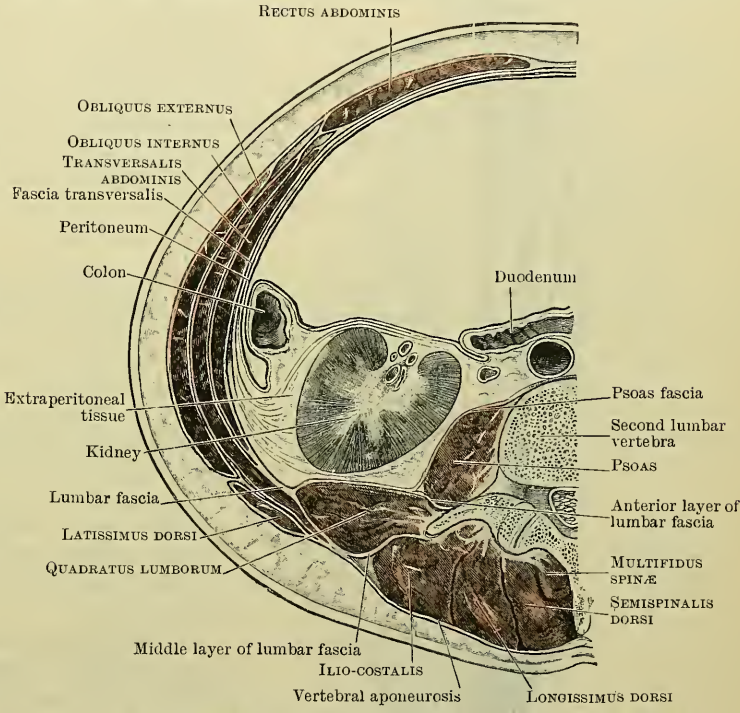


Fig. 306.—Transverse Section through the Abdomen, opposite the Second Lumbar Vertebra.

The **lumbar fascia** is a narrow ligamentous band which connects the last rib to the iliac crest between the muscles of the back on the one hand and those of the abdominal wall on the other. It is formed by the union of three fascial strata, called respectively the **vertebral aponeurosis** or posterior layer, just described; the middle, and the anterior layers. The **middle layer** is a fascia which stretches outwards from the ends of the transverse processes of the lumbar vertebræ, between the erector spinæ behind and the quadratus lumborum muscle in front. The **anterior layer** is attached to the lumbar vertebræ near the bases of their transverse processes. It covers the front of the quadratus lumborum muscle, and separates it from the psoas. The **psoas fascia** is continuous at the outer border of the psoas muscle with the anterior layer of the lumbar fascia. At the outer borders of the quadratus lumborum and erector spinæ muscles the three layers are blended together to form the lumbar fascia, which in turn gives partial origin to the obliquus internus and transversalis abdominis muscles.

THE MUSCLES OF THE BACK.

The muscles of the back are arranged in four series according to their attachments: (1) vertebro-scapular and vertebro-humeral, (2) vertebro-costal, (3) vertebro-cranial, and (4) vertebral. They are in irregular strata, the most superficial muscles having the most widely spread attachments.

The first series of muscles of the back, connecting the axial skeleton to the upper limb, have already been described. They are arranged in two layers: (1) trapezius and latissimus dorsi superficially; (2) levator anguli scapulæ, and rhomboidei, beneath the trapezius.

The remaining muscles are almost entirely axial, and may be divided, according to position, into four groups: (1) serrati postici, superior and inferior, splenius capitis and splenius colli; (2) erector spinæ and complexus; (3) transverso-spinales (semispinalis and multifidus spinæ); and (4) the small deep muscles (rotatores, interspinales, intertransversales, and suboccipital muscles).

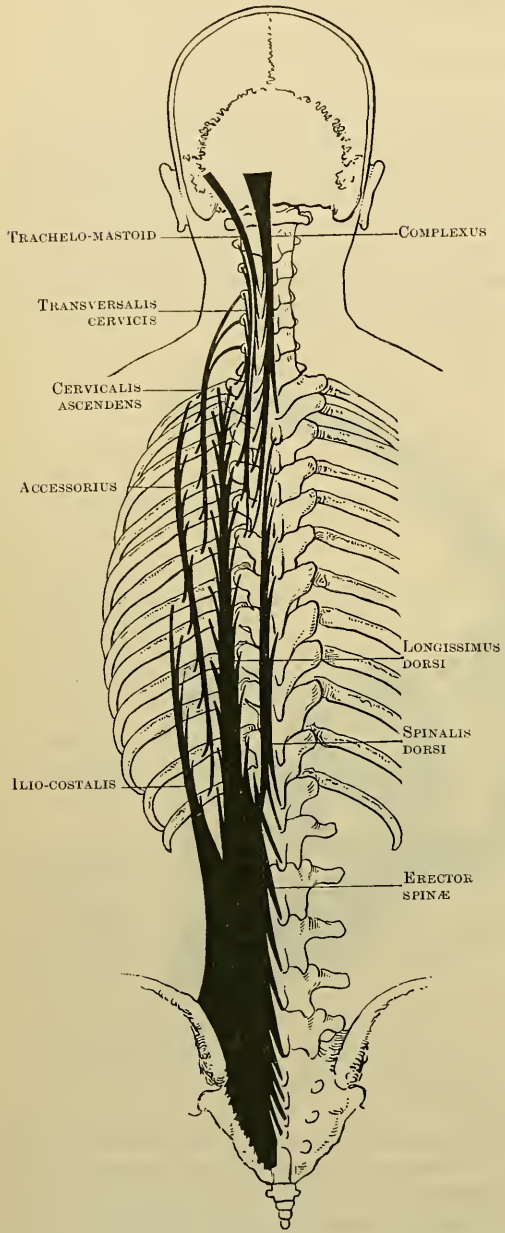


Fig. 307.—Schematic Representation of the Parts of the Erector Spinæ Muscle.

First Group.

The **serratus posticus superior** has a membranous **origin** from the ligamentum nuchæ and the spines of the last cervical and upper three or four thoracic vertebræ. It is directed obliquely downwards and outwards, to be **inserted** by separate slips into the second, third, fourth, and fifth ribs. The muscle is concealed by the vertebro-scapular muscles, and crosses obliquely the splenius, erector spinæ, and complexus. It lies superficial to the vertebral aponeurosis.

The **serratus posticus inferior** has a membranous **origin** through the medium of the vertebral aponeurosis from the last two thoracic and first two lumbar spinous processes. It forms four muscular bands which pass almost horizontally outwards to an **insertion** into the last four ribs. The muscular slips overlap one another from below upwards. The muscle is on the same plane as the vertebral aponeurosis, and is concealed by the latissimus dorsi.

The **splenius muscle** is a broad, flattened band which occupies the back of the neck and the upper part of the thoracic region. It **arises** from the ligamentum nuchæ (from the level of the fourth cervical vertebra downwards) and from the spinous processes of the last cervical and higher (four to six) thoracic vertebræ. Its fibres extend upwards and outwards into the neck, separating in their course into an upper and a lower part. The upper part forms the **splenius capitis**, which is **inserted** into the mastoid process and the outer part of the superior curved line of

the occipital bone (Fig. 312, p. 397). The lower part forms the **splenius colli or cervicis**, which is **inserted** into the posterior tubercles of the transverse processes of the upper three or four cervical vertebræ, behind the origin of the levator anguli scapulæ. The muscle is partially concealed by the trapezius and sterno-mastoid, and appears between them in the floor of the posterior triangle of the neck (splenius capitis). It is covered by the rhomboid muscles, levator anguli scapulæ, and serratus posticus superior. It conceals the transversalis cervicis, trachelo-mastoid, and complexus muscles.

Second Group.

The **erector spinæ** (m. sacro-spinalis) possesses vertebral, vertebro-cranial, and vertebro-costal attachments. It consists of an elongated mass composed of separated slips extending from the sacrum to the skull. Simple at its origin, it becomes more and more complex as it is traced upwards towards the head. It **arises** (1) by fleshy fibres from the iliac crest; (2) from the posterior sacro-iliac ligament; and (3) by tendinous fibres continuous with the former from the iliac crest, the back of the sacrum, and the spines of the upper sacral and all the lumbar vertebræ. Its fibres extend upwards through the loin, enclosed between the posterior and middle layers of the lumbar fascia, and separate into two columns—an outer portion derived from the external fleshy origin, the **ilio-costalis**, and an inner portion comprising the remaining larger part of the muscle, the **longissimus dorsi**.

The **ilio-costalis** (m. ilio-costalis lumborum) is **inserted** by six slender slips into the lower six ribs.

Internal to the insertion of each is the origin of a slip of the **accessorius muscle**

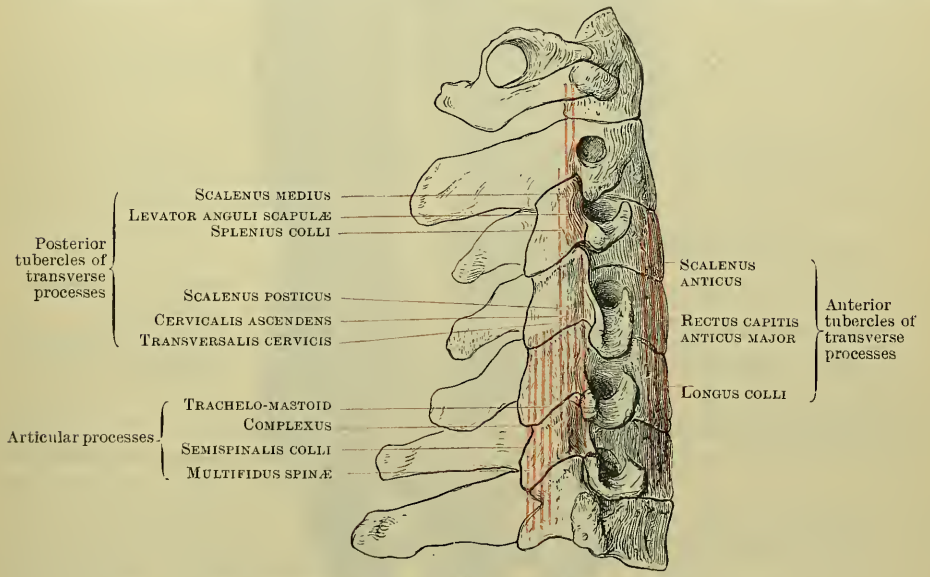


Fig. 308.—Scheme of Muscular-Attachments to the Transverse Processes of the Cervical Vertebræ.

(m. ilio-costalis dorsi), which, **arising** from the lower six ribs internal to the ilio-costalis, is **inserted** in line with it by similar slips into the upper six ribs.

The **cervicalis ascendens** (m. ilio-costalis cervicis) **arises** in the same way by six slips from the upper six ribs, internal to the insertions of the accessorius. It forms a narrow band, which, extending into the neck, is **inserted** into the posterior tubercles of the transverse processes of the fourth, fifth, and sixth cervical vertebræ, behind the scalenus posticus. The ilio-costalis, accessorius, and cervicalis ascendens form together a continuous muscular column, and constitute the outermost group of the component elements of the erector spinæ.

The **longissimus dorsi** is the largest element in the erector spinæ muscle.

With its cervical prolongations—the transversalis cervicis and trachelo-mastoid—it forms the middle column of the erector spinæ. Mostly tendinous on the surface at its origin, it becomes fleshy in the upper part of the loin. It is thickest in the loin, and becomes thinner as it passes upwards in the back between the column formed by the ilio-costalis, etc., externally, and the spinalis dorsi internally. It is **inserted** by two series of slips, inner and outer, externally into nearly all the

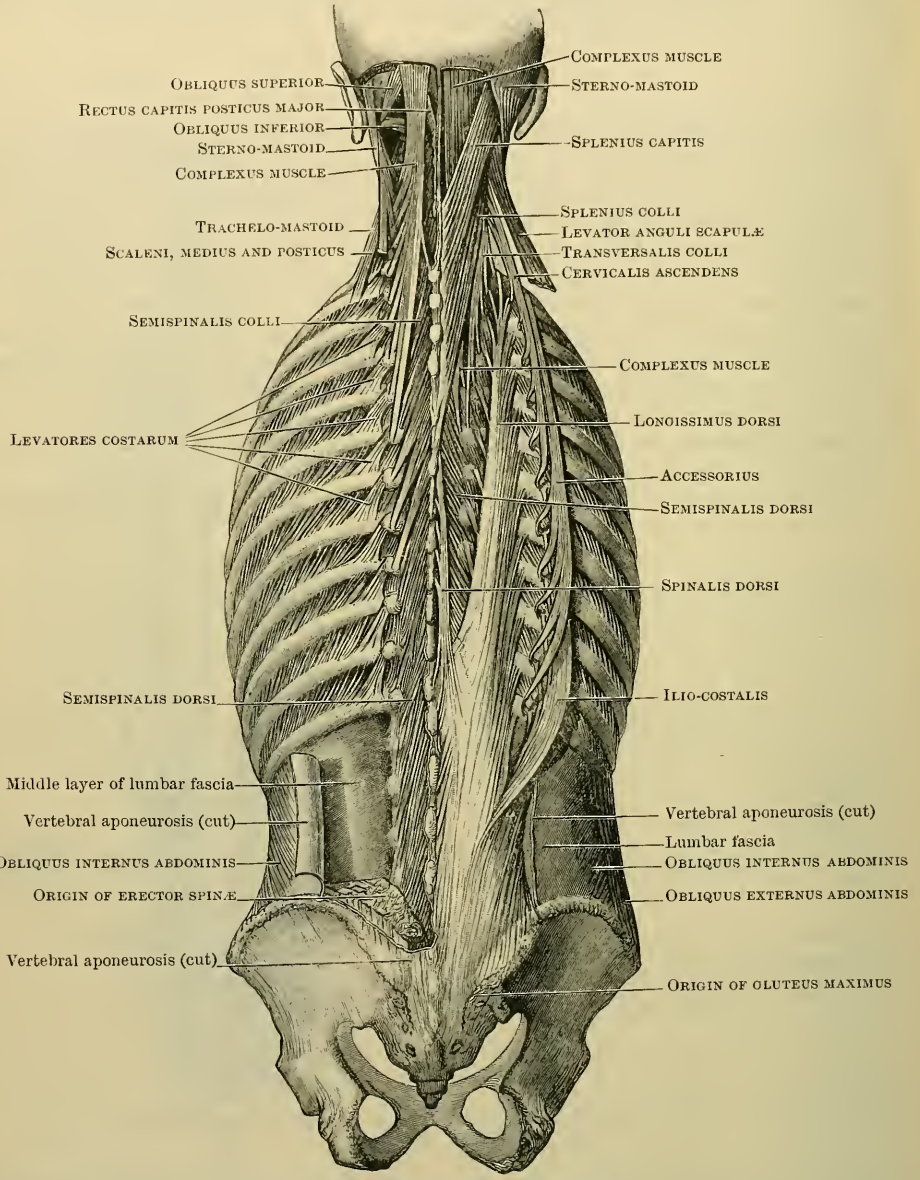


Fig. 309.—Deeper Muscles of the Back.

ribs, and internally into the transverse processes of the thoracic and the accessory processes of the upper lumbar vertebræ. It is prolonged upwards into the neck by its association with the common origin of two muscles, the transversalis cervicis and the trachelo-mastoid.

The **transversalis cervicis** (m. longissimus cervicis) has an **origin** from the transverse processes of the upper six thoracic vertebræ, internal to the insertions of the longissimus dorsi. Extending upwards into the neck, it is **inserted** into the

posterior tubercles of the transverse processes of the second, third, fourth, fifth, and sixth cervical vertebræ. It lies in the neck, underneath the cervicalis ascendens and splenius colli muscles.

The **trachelo-mastoid** (m. longissimus capitis) **arises**, partly by an origin common to it and the previous muscle, from the transverse processes of the upper six thoracic vertebræ, and partly by an additional origin from the articular processes of the lower four cervical vertebræ. Separating from the transversalis cervicis, the muscle ascends through the neck as a narrow band which is **inserted** into the mastoid process beneath the splenius capitis muscle. In the neck the muscle is placed between the splenius capitis and complexus.

The **spinalis dorsi** forms the innermost column of the erector spinæ. It occupies the thoracic portion of the back, and **arises** by tendinous fibres from the lower two thoracic and upper two lumbar spinous processes, and also directly from the tendon of the longissimus dorsi. It is a narrow muscle which, lying close to the thoracic spinous processes internal to the longissimus dorsi and complexus, is **inserted** into the upper (four to eight) thoracic spines. This muscle is not prolonged into the neck. It partially covers the semispinalis, dorsi, and colli.

The erector spinæ muscle is bound down by the vertebral aponeurosis, and is concealed by the more superficial muscles (sterno-mastoid, trapezius, levator anguli scapulæ, rhomboids, splenius, serrati postici). It covers the ribs posteriorly, and partially conceals the semispinales and complexus muscles.

The **complexus muscle** (m. semispinalis capitis) closely resembles in position and attachments the trachelo-mastoid. It takes **origin** by tendinous slips from the transverse processes of the upper six thoracic and the articular processes of the lower four cervical vertebræ, internal to the transversalis cervicis and trachelo-mastoid. It has an additional origin also from the spinous process of the last cervical vertebra. It forms a broad muscular sheet which extends upwards in the neck, to be **inserted** by fleshy and short tendinous fibres into the inner impression between the superior and inferior curved lines of the occipital bone (Fig. 312, p. 397). The inner portion of the muscle is separate, and forms the **biventer cervicis**, consisting of two fleshy bellies with an intervening tendon, placed vertically in contact with the ligamentum nuchæ. The insertion of the muscle is crossed by the occipital artery. The complexus is covered mainly by the splenius and trachelo-mastoid muscles. It conceals the semispinalis colli and the muscles of the suboccipital triangle, along with the accompanying vessels and nerves.

Third Group.

This group comprises the semispinales and multifidus spinæ.

These muscles are only incompletely separate from one another. The semispinales, dorsi, and colli, form a superficial stratum, the multifidus spinæ being more deeply placed. The more superficial muscles have the longer fibres; the fibres of the multifidus spinæ pass over fewer vertebræ. Both muscles extend obliquely upwards from transverse to spinous processes.

The **semispinalis muscle** extends from the loin to the axis vertebra. Its fibres are artificially separated into an inferior part, the **semispinalis dorsi**, and a superior part, the **semispinalis colli.**

The **semispinalis dorsi arises** from the transverse processes of the lower six thoracic vertebræ. It is **inserted** into the spinous processes of the last two cervical and first four thoracic vertebræ.

The **semispinalis colli** or **cervicis arises** from the transverse processes of the upper six thoracic vertebræ and the articular processes of the lower four cervical vertebræ. It is **inserted** into the spines of the cervical vertebræ from the second to the fifth. The semispinalis muscle occupies the vertebral furrow, and is concealed by the erector spinæ and complexus; it covers the multifidus spinæ muscle. It is on the same plane as the muscles of the suboccipital triangle.

The **multifidus spinæ** differs from the previous muscle in extending from the sacrum to the axis, and in the shortness of its fasciculi, which pass over fewer vertebræ to reach their insertion. It **arises** from the sacrum, from the posterior

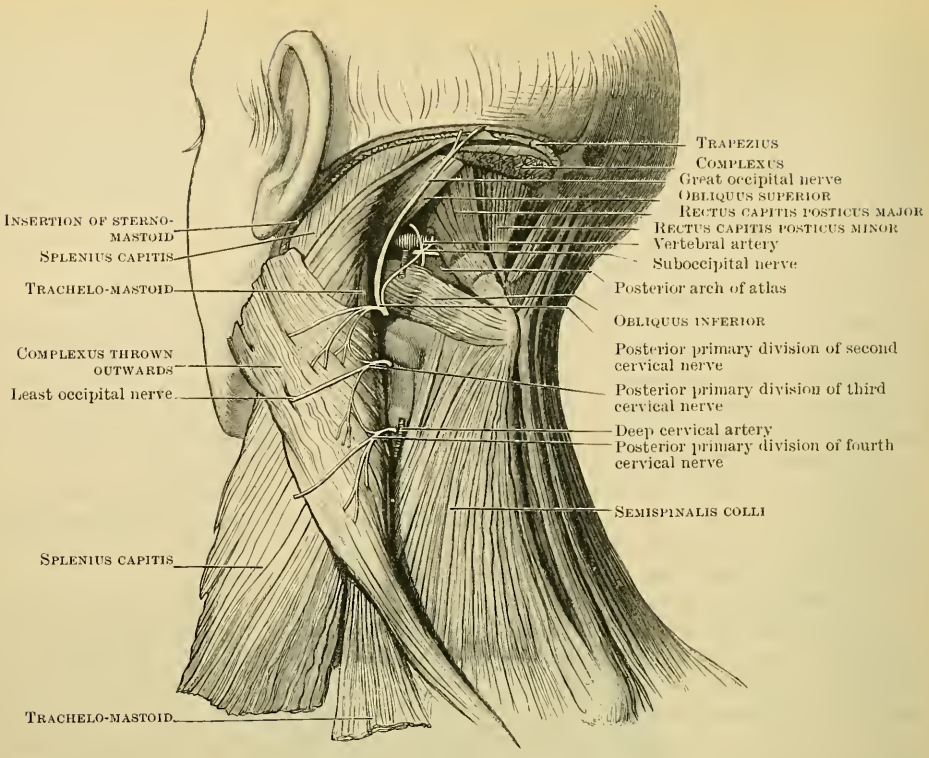


Fig. 310.—The Suboccipital Triangle.

sacro-iliac ligament (Fig. 311, p. 396), from the mammillary processes of the

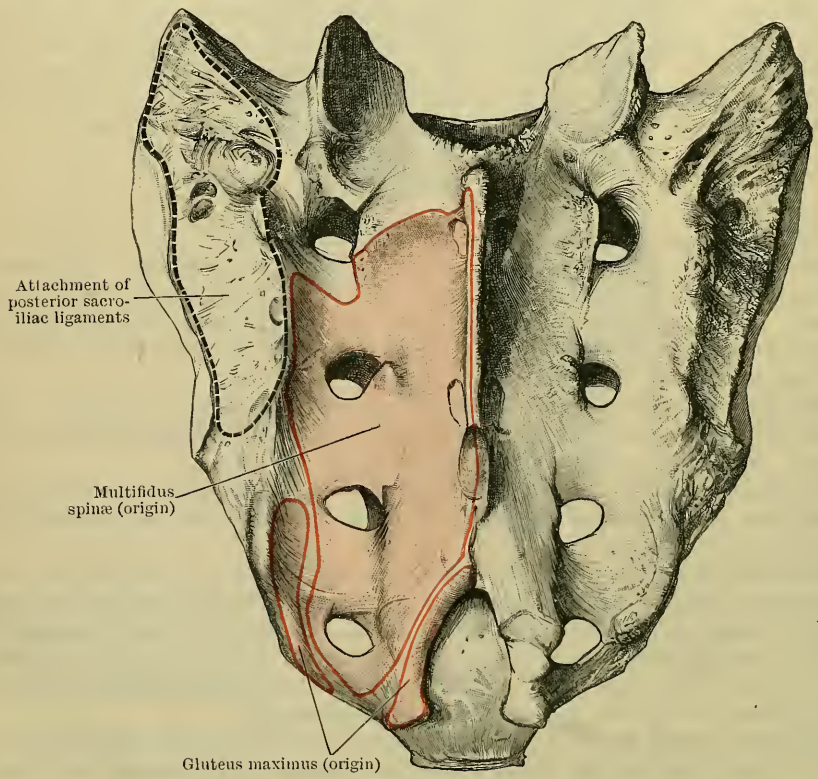


Fig. 311.—Muscle-Attachments to the Sacrum (Posterior Aspect).

lumbar vertebræ, from the transverse processes of the thoracic vertebræ, and from the articular processes of the lower four cervical vertebræ. It is **inserted** into the spines of the vertebræ up to and including the axis. Lying in contact with the vertebral laminæ, the muscle is covered in the back and neck by the semispinalis, and in the loin by the erector spinæ muscle.

Fourth Group.

This group includes several sets of small muscles, which are vertebro-cranial or inter-vertebral in their attachments.

The muscles bounding the **suboccipital triangle** are four in number—obliquus inferior, obliquus superior, rectus capitis posticus major, and rectus capitis posticus minor.

These muscles are concealed by the complexus and splenius capitis; they enclose a triangular space (the suboccipital triangle) in which the vertebral artery, the posterior primary division of the suboccipital nerve, and the posterior arch of

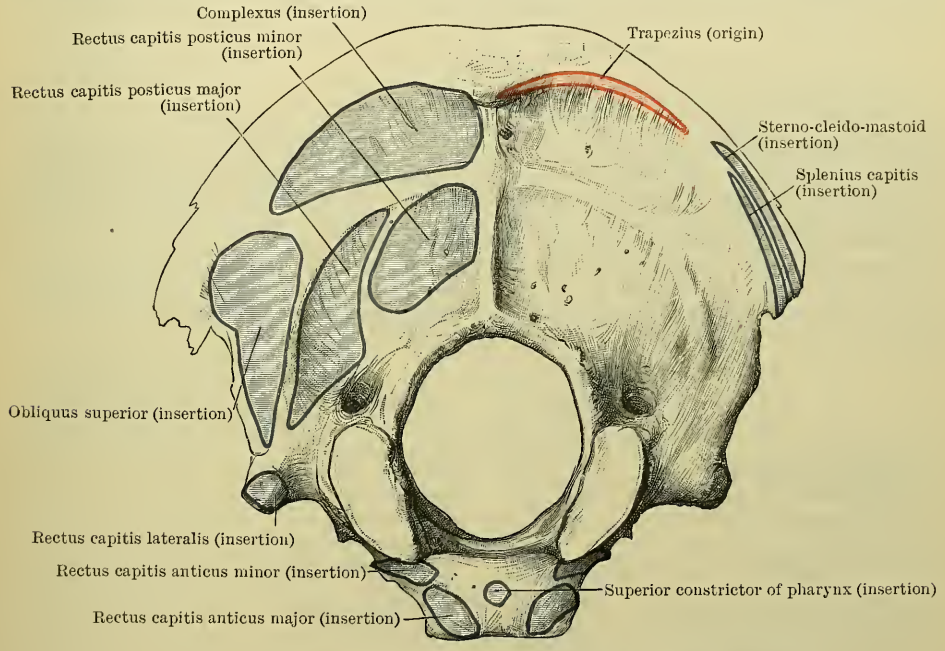


Fig. 312.—Muscle-Attachments to Occipital Bone (Inferior Surface).

the atlas are contained. The obliquus inferior is separated from the semispinalis muscle by the great occipital (second cervical) nerve.

The **obliquus inferior** arises from the spine of the axis, and is **inserted** into the transverse process of the atlas.

The **obliquus superior** arises from the transverse process of the atlas, and is **inserted** into the occipital bone beneath and external to the complexus and above the inferior curved line (Fig. 312, p. 397).

The **rectus capitis posticus major** arises from the spine of the axis, and is **inserted** into the occipital bone beneath the obliquus superior and complexus, and below the inferior curved line (Fig. 312, p. 397).

The **rectus capitis posticus minor** arises beneath the previous muscle from the spine of the atlas, and is **inserted** into the occipital bone below the inferior curved line internal to and beneath the rectus capitis posticus major (Fig. 312, p. 397).

The **rotatores dorsi** are eleven pairs of small muscles occupying the vertebral groove in the thoracic region, beneath the transverso-spinales, of which they form the deepest fibres. Each consists of a small slip **arising** from the transverse process, and **inserted** into the lamina of the vertebra directly above.

The **inter-spinales** are bands of muscular fibres connecting together the spinous processes of the vertebræ.

The **inter-transversales** are slender slips extending between the transverse processes. They are double in the neck, the anterior divisions of the spinal nerves passing between them.

The **rectus capitis lateralis**, extending from the transverse process of the atlas to the jugular process of the occipital bone (Fig. 312, p. 397), is homologous with the posterior of the two inter-transverse muscles. In the loin the inter-transversales muscles are usually double, but they are often absent, or are replaced by membrane.

Nerve-Supply.

With the exception of the vertebro-scapular and vertebro-humeral muscles (trapezius, latissimus dorsi, levator anguli scapulæ, rhomboidei, p. 318), the muscles of the back are all supplied by the *posterior primary divisions* of the spinal nerves. In the upper part of the trunk the muscles are supplied mainly by the external branches; in the lower part chiefly by the internal branches of the nerves. In the cervical and sacral regions a limited plexiform arrangement of the nerves occurs (*posterior cervical* and *posterior sacral plexuses*).

Actions.

The action of these muscles is extremely complex. Not only do they act on the spinal column, ribs, head, and pelvis, in conjunction with other muscles, but some of them act also in relation to the movements of the limbs as well. In this section will be given an analysis of their movements in relation to the spinal column, head, and pelvis. The movements of the limbs and of the ribs (respiration) are dealt with in other sections. The chief muscles are engaged in preserving the erect position, and in the movements of the trunk they are assisted in large measure by muscles whose chief movements are referred to elsewhere.

1. Movements of the Spinal Column.—The movements of the vertebral column are flexion, extension, and lateral movement or rotation. These movements occur in all regions—neck, thorax, and loin; flexion and extension and lateral movement are most limited in the region of the thorax; while rotation is most limited in the region of the loin.

a. **Flexion** and **Extension.**	
Longus colli	Serrati postici
Rectus capitis anticus major	Splenius capitis
Scaleni antici (together)	Splenius colli
Psoas magnus and parvus	Erector spinæ
Levator ani	Semispinalis dorsi
Ischio-coccygeus	Semispinalis colli
	Complexus
Sphincter ani externus	Multifidus spinæ
Rectus abdominis	Interspinales
Pyramidalis abdominis	
Obliquus externus abdominis	Intercostal muscles
Obliquus internus „	Diaphragm
Transversalis „	Triangularis sterni

b. **Lateral Movement (Rotation).**	
Levator anguli scapulæ	Rectus capitis anticus major
Serrati postici	Scaleni, anticus, medius, posticus
Splenius colli	Psoas (magnus and parvus)
Erector spinæ	Quadratus lumborum
Complexus	Obliquus externus abdominis
Semispinalis	Obliquus internus „
Multifidus spinæ	Transversalis „
Rotatores dorsi	Rectus „
Inter-transversales	Pyramidalis „
Longus colli	

2. Movements of the Head.—The movements of the head are flexion and extension, at the occipito-atlantoid articulation; lateral movement and rotation at the atlanto-axial joint.

a. **Flexion** and **Extension.**	
Digastric	Sterno-mastoid
Stylo-hyoid	Splenius capitis
Stylo-pharyngeus	Trachelo-mastoid
Mylo-hyoid	Complexus
Hyo-glossus	Obliquus inferior
Sterno-hyoid	Recti capitis postici (major and minor)
Sterno-thyroid	
Omo-hyoid	
Recti capitis antici (major and minor)	
(*the muscles of both sides acting together*)	

b. **Lateral Movement.**	*c.* **Rotation.**
Sterno-mastoid	Sterno-mastoid
Splenius capitis	Splenius capitis
Trachelo-mastoid	Trachelo-mastoid
Complexus	Complexus
Obliquus superior	Obliquus inferior
Rectus capitis lateralis	,, superior
	Recti capitis postici (major and minor)

Movements of the Pelvis.—The movements of the pelvis (as in locomotion) are partly caused by certain of the muscles of the back. Those muscles, which are attached to the spinal column or the ribs on the one hand, and to the innominate bone on the other, produce the movements (flexion, extension, and lateral movement) of the whole pelvis. In addition, the muscles passing between the innominate bone and femur, in certain positions of the lower limb, assist in these movements.

a. **Extension** and **Flexion.**	
Latissimus dorsi	Psoas magnus and parvus
Erector spinæ	Rectus abdominis
Multifidus spinæ (acting on both sides)	Pyramidalis abdominis
	Obliquus externus abdominis
	Obliquus internus ,,
	Transversalis abdominis (acting on both sides)
	Pyriformis
	Glutei
	Obturator (externus and internus)
	Sartorius
	Tensor fasciæ femoris
	Iliacus
	Rectus femoris
	Adductors (in the erect position)
b. **Lateral Movement.**	
Flexors and extensors of side only	Quadratus lumborum

THE FASCIÆ AND MUSCLES OF THE HEAD AND NECK.

FASCIÆ.

The **superficial fascia** of the head and neck possesses certain features of special interest. Over the scalp it is closely adherent to the skin and subjacent epicranial aponeurosis, and contains the superficial vessels and nerves. Beneath the skin of the eyelids it is loose and thin and contains no fat. Over the face and at the side of the neck it is separated from the deep fascia by the facial muscles and the platysma myoides. In the hollow between the buccinator and the masseter it is continuous with a pad of fat (*suctorial pad*) occupying the interval between these muscles.

The **deep fascia** of the head and neck presents many remarkable characters. *Over the scalp* it is represented by the **epicranial aponeurosis,** the tendon of the occipito-frontalis muscle. This is a tough membrane, tightly stretched over the calvarium, from which it is separated by loose areolar tissue. It is attached posteriorly, partly through the agency of the occipitalis muscle, to the superior curved line of the occipital bone; anteriorly it joins the frontalis muscle and the orbicularis palpebrarum, and has no bony attachment; laterally it is attached to the temporal ridge and the mastoid process. Below the temporal ridge it is continuous with the **temporal fascia,** a stout layer of fascia attached to the temporal ridge and zygomatic arch, which covers and gives origin to the temporal muscle. This fascia separates into two layers above the zygoma, to enclose a quantity of fat along with branches of the temporal and orbital arteries. On the face the fascia is practically non-existent anteriorly in relation to the facial muscles. Posteriorly it forms the thin **masseteric fascia,** and is much thicker in relation to the parotid gland, for which it forms a capsule.

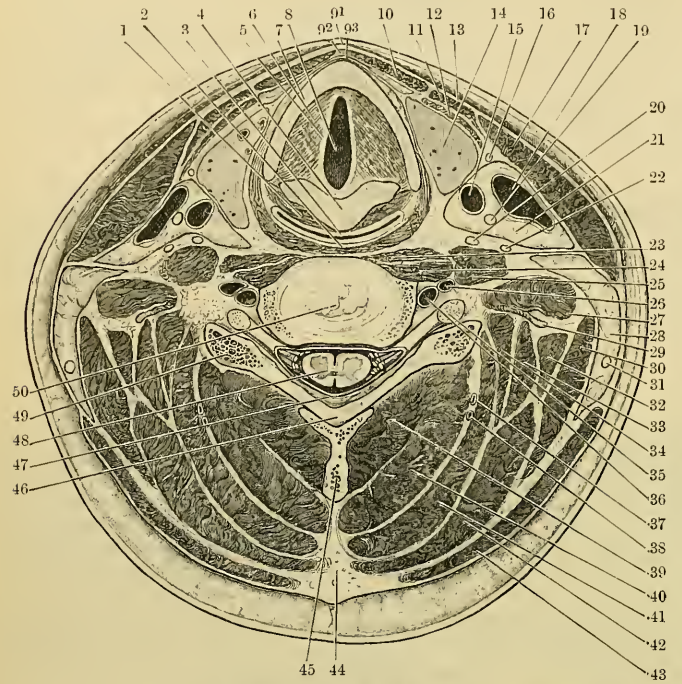


FIG. 313.—TRANSVERSE SECTION IN THE CERVICAL REGION (between the fourth and fifth cervical vertebræ).

1. CRICO-THYROID MUSCLE.
2. INFERIOR CONSTRICTOR MUSCLE.
3. Pharynx.
4. Cricoid cartilage.
5. Vocal cord.
6. THYRO-ARYTENOID MUSCLE.
7. Thyroid cartilage.
8. Glottis.
9. Layers of deep cervical fascia.
10. STERNO-HYOID MUSCLE.
11. OMOHYOID MUSCLE.
12. STERNO-THYROID MUSCLE.
13. Cervical fascia.
14. Thyroid body.
15. Common carotid artery.
16. Descendens hypoglossi nerve.
17. STERNO-MASTOID MUSCLE.
18. Internal jugular vein.
19. Pneumogastric nerve.
20. Sympathetic nerve.
21. Carotid sheath.
22. Phrenic nerve.
23. LONOUS COLLI MUSCLE.
24. RECTUS CAPITIS ANTICUS MAJOR.
25. SCALENUS ANTICUS.
26. Vertebral vein.
27. SCALENUS MEDIUS.
28. Posterior triangle.
29. SCALENUS POSTICUS.
30. LEVATOR ANGULI SCAPULÆ.
31. Spinal accessory nerve.
32. SPLENIUS COLLI.
33. TRANSVERSALIS CREVICIS.
34. TRACHELO-MASTOID.
35. Spinal nerve.
36. Vertebral artery.
37. Profunda cervicis vein.
38. Profunda cervicis artery.
39. MULTIFIDUS SPINÆ.
40. SEMISPINALIS COLLI.
41. COMPLEXUS.
42. SPLENIUS CAPITIS.
43. TRAPEZIUS.
44. Ligamentum nuchæ
45. Spine of fourth cervical vertebra.
46. Lamina of fifth cervical vertebra.
47. Dura mater.
48. Spinal cord.
49. Transverse process.
50. Disc between fourth and fifth cervical vertebræ.

In the neck the deep fascia invests the muscles, and forms aponeurotic coverings for the pharynx, trachea, œsophagus, glands, and large vessels. It encloses the sterno-mastoid muscle, and can be traced backwards over the posterior triangle to the trapezius and deeper muscles, which it surrounds; it can be traced forwards over the anterior triangle to the middle line of the neck, where it forms a continuous membrane. *Above the sternum* the fascia, after enclosing the sterno-mastoid muscles, is attached in the form of two layers to the front and back of the episternal notch. The layer enclosing the infrahyoid muscles passes across the middle line of the neck in front of the trachea, and is attached above to the hyoid bone, below to the sternum, clavicle, and first rib. A third layer of fascia passes inwards in front of the trachea, enclosing the thyroid body. Beneath the sterno-mastoid the fascia helps to form the **carotid sheath,** which is completed by septal processes stretching inwards across the neck in relation to the infrahyoid muscles, trachea, œsophagus, and pharynx, and the prevertebral muscles. The trachea,

œsophagus, and pharynx, are likewise encapsuled in cervical fascia, a septal layer passing across the middle line of the neck between the trachea and œsophagus. Lastly, a strong **prævertebral fascia** passes across the neck in front of the prævertebral muscles, and behind the œsophagus and pharynx.

The cervical fascia is attached above to the **bones of the skull**: superficially to the superior curved line of the occipital bone, the mastoid process, the zygoma (over the parotid gland), and the lower border of the mandible; more deeply to the styloid and vaginal processes of the temporal bone, the great wing of the sphenoid and the basilar process. This deeper attachment (*prævertebral fascia*) is behind the parotid gland and pharynx, and is associated with the formation of three ligaments: **stylo-mandibular ligament, internal lateral ligament** of the lower jaw, and **pterygo-spinous ligament.** The fascia is attached below, through its muscular connexions, to the sternum, first rib, clavicle, and scapula. By means of its connexion with the trachea and the common carotid artery it is carried down behind the first rib into the superior mediastinum, and so becomes continuous with the pericardium. By means of its connexion with the subclavian vessels and brachial nerves it is carried down to the axilla, as the subclavian sheath, which becomes connected with the costo-coracoid membrane.

THE MUSCLES OF THE HEAD.

The muscles of the head are divisible into three separate groups with very different relations and uses—viz., superficial muscles, muscles of the orbit, and muscles of mastication.

Superficial Muscles.

The superficial muscles comprise a large group, including the muscles of the scalp and face, and the platysma myoides in the neck.

The **platysma myoides** is a thin quadrilateral sheet extending from chest to face over the side of the neck, between the superficial and deep fasciæ. It **arises** from the deep fascia of the pectoral region and the clavicle. It is directed upwards and forwards, and is partly **inserted** (by its intermediate fibres) into the lower border of the mandible, becoming connected with the depressor labii inferioris and depressor anguli oris muscles (Fig. 319, p. 407). The more anterior fibres pass across the middle line of the neck and decussate for a variable distance below the chin with those of the opposite side. The posterior fibres sweep over the angle of the jaw and become continuous with the risorius muscle. The platysma myoides is the rudiment of the cervical portion of the **panniculus carnosus** of lower animals, in which it has a much more intimate connexion with the muscles of the face than is usually the case in man.

The Muscles of the Scalp.

The muscles of the scalp comprise the muscles of the external ear and the occipito-frontalis muscle.

The **occipito-frontalis** is a muscle with two bellies and an intervening tendon (the epicranial aponeurosis) which stretches uninterruptedly across the middle line of the cranium. The **posterior belly** (occipitalis) **arises** as a broad flat band from the outer two-thirds of the superior curved line of the occipital bone. The **anterior belly** (frontalis) has no bony attachments; **arising** from the epicranial aponeurosis about the level of the coronal suture, it passes downwards to the supra-orbital arch, where it blends with the orbicularis palpebrarum and corrugator supercilii muscles. It extends across the full width of the forehead, and blends in the middle line with the muscle of the opposite side.

The **epicranial aponeurosis,** extending between the two fleshy bellies, is a continuous membrane which glides over the calvarium, and has attachments laterally to the temporal ridge, and behind, between the posterior bellies, to the superior curved line of the occipital bone. It has no osseous attachment anteriorly. The occipito-frontalis is usually rudimentary. By the contraction of the fibres of the frontalis muscle the skin of the forehead is thrown into horizontal parallel folds.

The **extrinsic muscles of the ear** are three in number: retrahens, attollens, and attrahens aurem.

The **retrahens aurem** (m. auricularis posterior) is a narrow fleshy slip which **arises** from the surface of the mastoid process and is **inserted** into the deep surface of the pinna. It bridges across the groove between the mastoid process and the pinna, and conceals the posterior auricular vessels and nerve.

The **attollens aurem** (m. auricularis superior) is a small fan-shaped muscle which **arises** from the temporal fascia, and descends to be **inserted** into the top of the root of the pinna.

The **attrahens aurem** (m. auricularis anterior) is a similar small muscle, placed in front of the attollens, and stretching obliquely between the temporal fascia and the top of the root of the pinna.

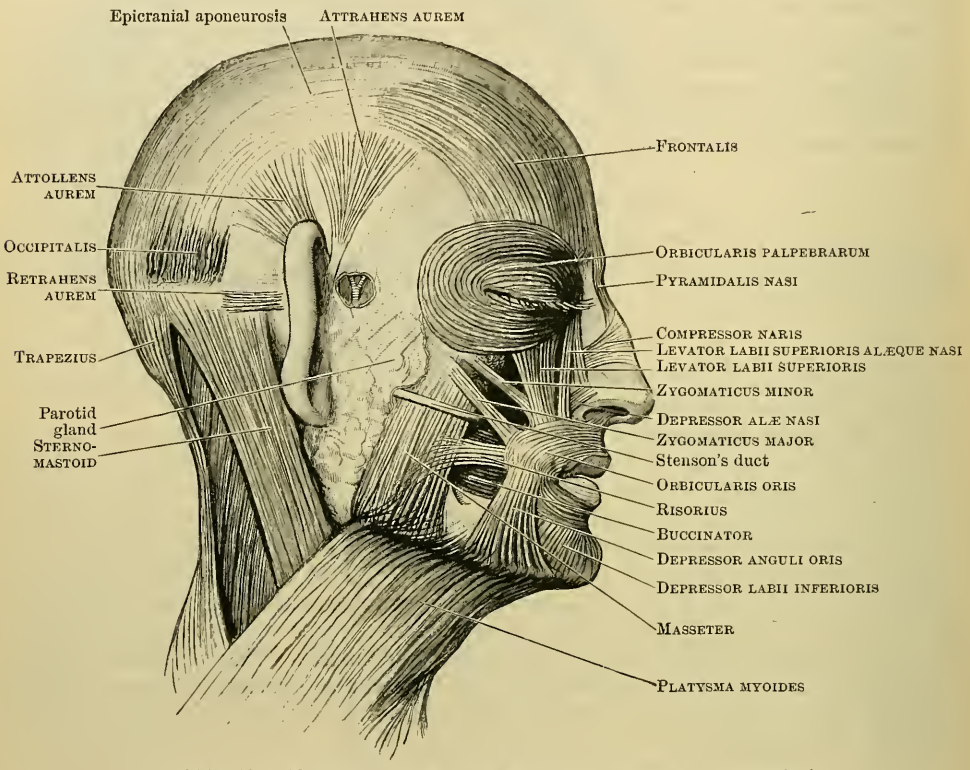


Fig. 314.—The Muscles of the Face and Scalp (muscles of expression).

These two muscles conceal branches of the temporal vessels as they lie on the temporal fascia.

The ear muscles are rudimentary and usually functionless.

The Muscles of the Face.

The facial muscles are divided into three groups, associated with the several apertures of the eye, nose, and mouth.

1. The **muscles of the eyelids** include four muscles: the levator palpebræ superioris (described with the orbital muscles), orbicularis palpebrarum, tensor tarsi, and corrugator supercilii.

The **orbicularis palpebrarum** (m. orbicularis oculi) is a transversely oval sphincter muscle surrounding and occupying the eyelids. It is divisible into an *external portion* (pars orbitalis) composed of coarse fibres, spreading on to the forehead, temple, and cheek, and an *internal portion* (pars palpebralis), composed of finer fibres, situated beneath the skin of the eyelids. At the inner canthus of the eye the muscle (by its palpebral fibres) gains an **attachment** to the tarsal ligament

and the borders of the naso-lachrymal groove. Its fibres enclose the lachrymal sac and the canaliculi. The posterior fibres, extending between the posterior edge of the naso-lachrymal groove and the tarsal ligaments behind the lachrymal sac, constitute the **tensor tarsi muscle.** The fibres of the muscle which extend along the margins of the lids constitute a separate **ciliary bundle.**

Externally the orbicularis palpebrarum has no bony attachment; so that when it contracts and closes the eyelids, both lids at the same time tend to be drawn inwards towards the inner canthus of the eye.

The **corrugator supercilii arises** from the nasal eminence, and passing horizontally outwards, blends with the upper fibres of the orbicularis palpebrarum on its under surface. The contraction of this muscle throws the skin of the forehead into vertical folds, while at the same time drawing the inner half of the eyebrow upwards, it produces concentric curved folds on each side of the middle line of the forehead.

2. The **muscles of the nose** comprise five small muscles proper to the nose, and one common to the nose and upper lip: the pyramidalis nasi, compressor naris, dilatores naris (anterior and posterior), depressor alæ nasi, and levator labii superioris alæque nasi. They are all small and feeble.

The **pyramidalis nasi arises** from the occipito-frontalis muscle and the skin over the glabella; it is **inserted** into a membrane stretching over the nose, which also gives attachment to the compressor naris.

The **compressor naris** (m. nasalis) **arises** by a narrow origin from the superior maxilla, under cover of the levator labii superioris alæque nasi. It passes forwards over the bridge of the nose, and ends in a membranous **insertion** common to it and the previous muscle.

The **dilatores naris** are feeble muscular slips placed on the outer side of the margin of the nostril, one anteriorly, the other posteriorly.

The **depressor alæ nasi** is a small muscle **arising** from the upper part of the incisor fossa of the maxilla; it divides into two parts as it passes upwards and inwards, and is **inserted** into the ala and the septum of the nose (depressor septi).

The **levator labii inferioris alæque nasi** is a narrow band **arising** from the root of the nasal process of the maxilla. It descends alongside the nose, and is **inserted** partly into the ala of the nose and partly into the orbicularis oris muscle.

3. The **muscles of the mouth** comprise eleven muscles, of which all but one, the orbicularis oris, are bilaterally placed. The muscles are: levator labii superioris alæque nasi, levator labii superioris, levator anguli oris, zygomatici (major and minor), risorius, orbicularis oris, depressor anguli oris, depressor labii inferioris, levator menti, and buccinator.

The **orbicularis oris** is the sphincter muscle surrounding the lips. It is continuous with the other muscles converging to the mouth. It lies between the skin and mucous membrane of the mouth, and is limited above by the nose, below by the junction of lower lip and chin. Its mesial fibres are attached above to the septum of the nose (naso-labial band) and to the incisor fossa (superior incisive bundle); below they are attached to the lower jaw on each side of the symphysis (inferior incisive bundle). These bundles radiate outwards to join the rest of the muscle, which is joined at its margin by the levators and depressors of the lower lip and angle of the mouth, and by the buccinator muscle. The *lower fibres* of the muscle are continued laterally into the buccinator and levator anguli oris; its *upper fibres* are continued into the buccinator and depressor anguli oris.

The **levator labii superioris alæque nasi** has already been described.

The **levator labii superioris arises** from the superior maxilla just above the infra-orbital foramen. It passes almost vertically downwards to join the orbicularis oris and the skin of the upper lip between the attachments of the levator labii superioris alæque nasi and the levator anguli oris. It conceals the infra-orbital vessels and nerve.

The **levator anguli oris arises** from the canine fossa of the upper jaw below the infra-orbital foramen and under cover of the foregoing muscle. It is directed outwards and downwards, to be **inserted** into the orbicularis oris and the skin at the angle of the mouth.

The **zygomatici (major and minor)** are more superficial than the preceding muscle.

The **zygomaticus minor** is the anterior muscle. It **arises** from the malar bone, and is often continuous with the most peripheral fibres of the orbicularis palpebrarum. It is directed obliquely downwards and forwards over the levator anguli oris, to be **inserted**, along with the levator labii superioris, into the orbicularis oris. The **zygomaticus major** is a narrow muscular band which **arises** from the malar portion of the zygomatic arch. It passes to the angle of the mouth, to be **inserted** partly into the skin, partly into the orbicularis oris.

The **risorius** is a thin flat muscle which forms in part a continuation of the platysma myoides on the face, in part a separate muscle, with an **origin** from the masseteric fascia. It passes transversely forwards, to be **inserted** at the angle of the mouth into the orbicularis oris and skin.

The **depressor anguli oris arises** from the external oblique line of the lower jaw and from the platysma myoides (Fig. 319, p. 407). It is triangular in form, its fibres converging to the angle of the mouth, where they are **inserted** into the orbicularis oris and the skin. Some of the fibres reach the upper lip through the orbicularis muscle.

The **depressor labii inferioris arises** from the outer surface of the lower jaw beneath and internal to the depressor anguli oris (Fig. 319, p. 407). It is quadrilateral in form, and is directed upwards, to be **inserted** into the orbicularis oris and the skin of the lower lip. Its external fibres conceal the mental foramen, and are overlapped by the depressor anguli oris. Its internal fibres join with those of the opposite muscle.

The **levator menti** is a small muscle which **arises** from the incisor fossa of the lower jaw (Fig. 319, p. 407), and passing forwards, is **inserted** into the skin of the chin.

The **buccinator muscle** forms the lateral wall of the mouth, and is in series posteriorly with the constrictor muscles of the pharynx. It **arises** (1) from the alveolar arches of the upper and lower jaws (Fig. 319, p. 407), and between these attachments, from the pterygo-mandibular ligament. Its fibres are directed forwards to the angle of the mouth, where they blend with the corresponding (upper and lower) portions of the orbicularis oris muscle. The *middle fibres* of the muscle decussate at the angle of the mouth, so as to pass, the lower set to the upper lip, the upper set to the lower lip. The buccinator is covered on its deep surface by the mucous membrane of the mouth. Superficially it is concealed by the muscles above mentioned, which converge to the angle of the mouth; it is separated from the masseter by the *suctorial pad of fat*; it is pierced by the duct of the parotid gland, and by branches of the long buccal nerve.

Nerve-Supply.

The facial and scalp muscles are all innervated by the **facial nerve**. The *posterior auricular branch* supplies the retrahens aurem and occipitalis; the branches forming the *pes anserinus* supply the frontalis, attollens, and attrahens aurem, the several muscles associated with the apertures of the eye, nose, and mouth (including the buccinator), and the platysma myoides.

Actions.

The almost infinite variety of facial expression is produced partly by the action of these muscles, partly by their inactivity, or by the action of antagonising muscles (antithesis). On the one hand joy is, for example, betrayed by the action of one set of muscles, while grief is accompanied by the contraction of another (opposing) set. Determination or eagerness is accompanied by a fixed expression due to a combination of muscles acting together; despair, on the other hand, is expressed by a relaxation of muscular action. For a philosophical account of the action of the facial muscles, the student should consult Darwin's *Expression of the Emotions in Man and Animals*, and Duchenne's *Mechanisme de la Physiologie humaine*.

The **platysma myoides** retracts and depresses the angle of the mouth, and depresses the lowe jaw. The **occipito-frontalis**, by its anterior belly, raises the eyebrows; both bellies acting together tighten the skin of the scalp; acting along with the orbicularis palpebrarum, it shifts the scalp backwards and forwards. The **corrugator supercilii** draws inwards the eyebrow and vertically wrinkles the skin of the forehead. The **pyramidalis nasi** draws downwards the skin between the eyebrows, as in frowning. The upper eyelid is raised by the **levator palpebræ superioris**. The closure of the lids is effected by the **orbicularis palpebrarum**, whose fibres also

assist in the lowering of the eyebrows, in the protection of the eyeball, and, by pressure on the lachrymal gland, in the secretion of tears. The **tensor tarsi**, acting along with the orbicularis palpebrarum, compresses the lachrymal sac and aids in the passage of its contents into the nasal duct. The **muscles of the ear** and **nose** have quite rudimentary actions expressed by their names. Of the muscles of the mouth, the **orbicularis oris** has a complex action, depending on the degree of contraction of its component parts. It causes compression and closure of the lips in various ways, tightening the lips over the teeth, contracting them as in osculation, or causing pouting or protrusion of one or the other. The **accessory muscles** of the **lips** draw them upwards (zygomatici, levator anguli oris, levator labii superioris alæque nasi, levator labii superioris), outwards (zygomaticus major, risorius, platysma, depressor anguli oris, buccinator), and downwards (depressor anguli oris, depressor labii inferioris, platysma). The **levator menti** elevates the skin of the chin and protrudes the lower lip. The **buccinator** retracts the angles of the mouth, flattens the cheeks, and brings them in contact with the teeth.

The Fascia and Muscles of the Orbit.

The eyeball with its muscles, vessels, and nerves, is lodged in a mass of soft and yielding fat which entirely fills up the cavity of the orbit. Surrounding the posterior part of the eyeball is the **capsule of Tenon**, which constitutes a large lymph space or synovial bursa in relation to the eyeball. Anteriorly the capsule is in contact with the conjunctiva, and intervenes between the latter and the eyeball; posteriorly it is pierced by and prolonged along the optic nerve. It is a smooth membrane connected to the globe of the eye by loose areolar tissue. It is pierced by the tendons of the ocular muscles, along which it sends prolongations continuous with the muscular sheaths.

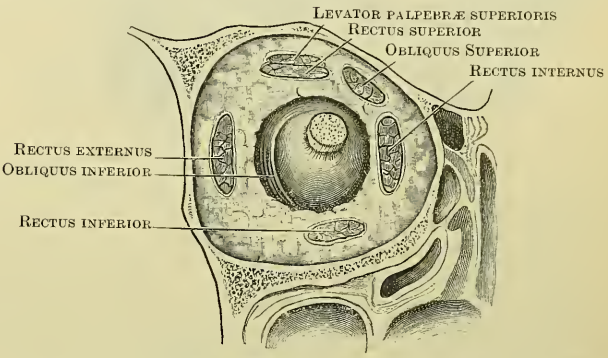


Fig. 315.—Transverse Vertical Section through the Orbit behind the Eyeball to show the Arrangement of Muscles.

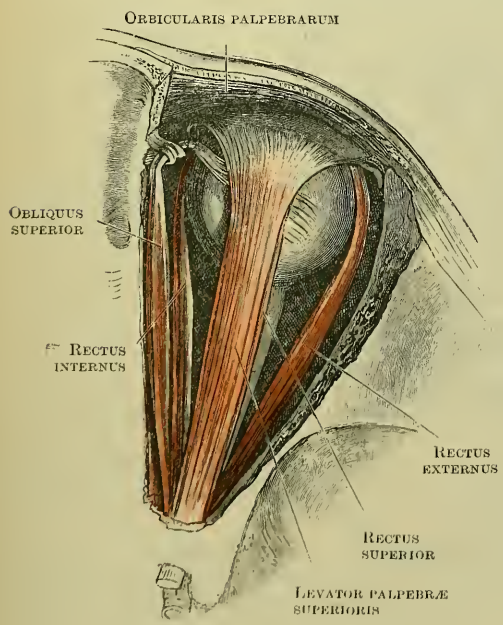


Fig. 316.—The Muscles of the Orbit (from above).

The **muscles of the orbit** are seven in number: one, the levator palpebræ superioris, belongs to the upper eyelid; the other six are muscles of the eyeball.

The **levator palpebræ superioris** lies immediately beneath the orbital periosteum and covers the superior rectus muscle. It has a narrow **origin** above that muscle from the margin of the optic foramen. It expands as it passes forwards, to end, in relation to the upper lid, in a membranous expansion which is **inserted** in a fourfold manner: (1) slightly into the orbicularis palpebrarum and skin of the upper lid, (2) mainly into the upper border of the tarsal cartilage, (3) slightly into the conjunctiva, and (4) by its edges into the upper border of the margin of the orbital opening.

The **recti muscles** are four in number—**superior, inferior, internal,** and **external.** They all **arise** from a membranous ring surrounding the optic foramen, which is separable into two parts—a *superior common tendon*, giving origin to the superior and internal

recti and the upper head of the external rectus; and an *inferior common tendon*, giving origin to the internal and inferior recti and the lower head of the external rectus. The two origins of the external rectus muscle are separated by the passage into the orbit of the oculo-motor, nasal, and abducent nerves. Forming flattened bands which traverse the fat of the orbit around the optic nerve and eyeball, the four muscles end in tendons which pierce the capsule of Tenon, and are **inserted** into the sclerotic about eight millimetres (three to four lines) behind the margin of the cornea. The **superior** and **inferior recti** are inserted in the vertical plane slightly internal to the axis of the eyeball; the **external** and **internal recti** in the transverse plane of the eyeball; and all are attached in front of the equator of the eyeball.

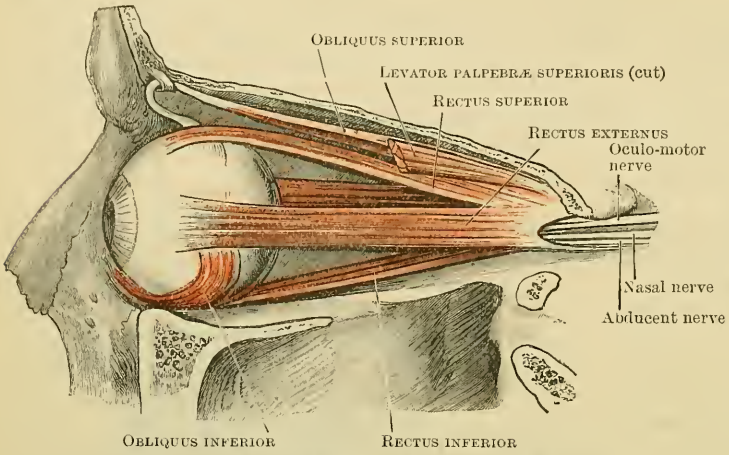


Fig. 317.—The Muscles of the Orbit (from without).

The **obliquus superior** arises from the margin of the optic foramen between the recti superior and internus. It passes forwards as a narrow muscular band internal to the rectus superior, and at the anterior margin of the orbit forms a narrow tendon which passes through a special fibrous pulley (trochlea) attached to the roof of the orbit. Its direction is then altered, and passing outwards

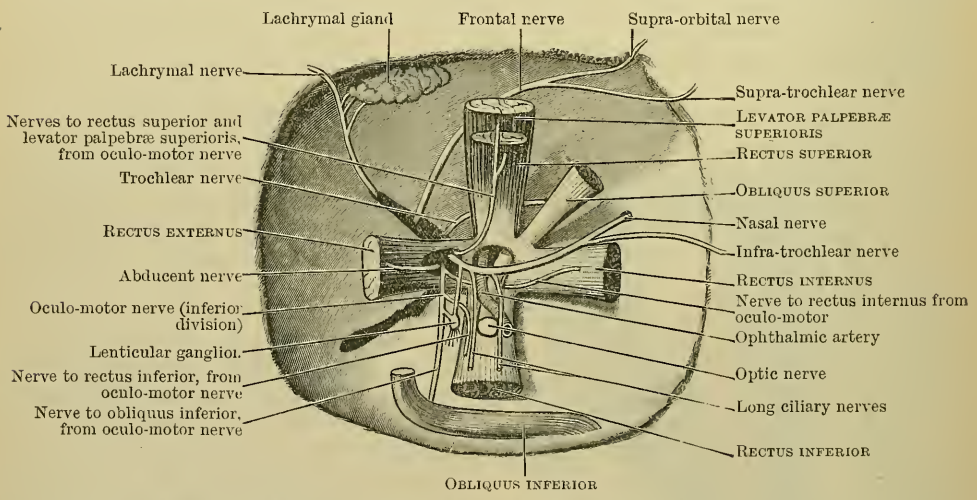


Fig. 318.—Schematic Representation of the Nerves which traverse the Cavity of the Orbit.

between the tendon of the superior rectus and the eyeball, it is **inserted** into the sclerotic between the superior and external recti, midway between the margin of the cornea and the entrance of the optic nerve.

The **obliquus inferior** arises from the inner side of the floor of the orbit just behind its anterior margin, and external to the naso-lachrymal groove. It forms a slender rounded slip, which curls round the inferior rectus tendon, and passes between the external rectus and the eyeball, to be **inserted** into the sclerotic between the superior and external recti, and farther back than the superior oblique muscle.

Müller's muscle is a rudimentary bundle of non-striated muscular fibres bridging across the

spheno-maxillary fissure and infra-orbital groove. It is supplied by fibres from the sympathetic, and may have a slight influence in the protrusion of the eyeball.

Nerve-Supply.

The muscles of the orbital cavity are supplied by the third, fourth, and sixth cranial nerves. The **fourth nerve** (trochlearis) supplies the obliquus superior; the sixth (abducens) supplies the rectus externus; the **third nerve** (motor oculi) supplies the others—levator palpebræ superioris, recti, superior, inferior and internus, and obliquus inferior.

Actions.

The **levator palpebræ superioris** elevates the upper eyelid and antagonises the orbicularis palpebrarum muscle. The six muscles inserted into the eyeball serve to move the longitudinal axis of the eyeball upwards, downwards, inwards, and outwards, besides causing a rotation of the eyeball on its own axis. The following table expresses the action of individual muscles. It must be remembered that, while similar movements occur simultaneously in the two eyeballs, the horizontal movements may, by adduction of the muscles of both sides, cause convergence of the axes of the two eyeballs for the purposes of near vision.

a. **Adduction** and **Abduction.**	
Rectus internus Rectus superior } Rectus inferior }	Rectus externus Obliquus superior } (*correcting* Obliquus inferior } *adductors*)
b. **Elevation** and **Depression.**	
Rectus superior Obliquus inferior	Rectus inferior Obliquus superior
c. **Rotation outwards.**	**Rotation inwards.**
Obliquus inferior	Obliquus superior Rectus superior } Rectus inferior } (*in adduction*)

Muscles of Mastication.

The muscles of mastication comprise the masseter, temporal, external and internal pterygoids, and buccinator (described above).

The **masseter** has an **origin** which is partly tendinous and partly fleshy. It arises in two parts: (1) superficially from the lower border of the zygoma in its anterior two-thirds, and (2) more deeply from the deep or inner surface of the zygoma in its whole length. The superficial fibres are directed downwards and backwards towards the angle of the jaw; the deeper fibres are directed vertically downwards. The muscle is **inserted** by fleshy and tendinous fibres into the outer surface of the ramus and angle of the lower jaw and the coronoid process (Fig. 319, p. 407). The deepest fibres blend with the fibres of the subjacent temporal muscle.

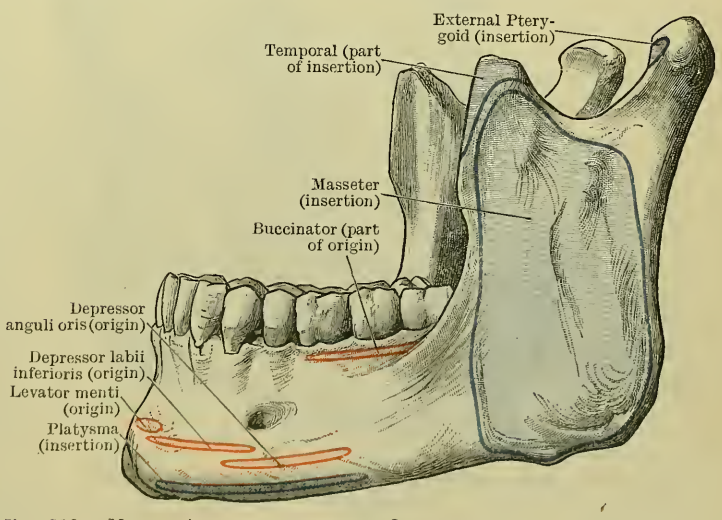


Fig. 319.—Muscle-Attachments to the Outer Aspect of the Lower Jaw.

The masseter muscle occupies the posterior part of the cheek. It is covered by the parotid gland, and is crossed by Stenson's duct and the branches of the

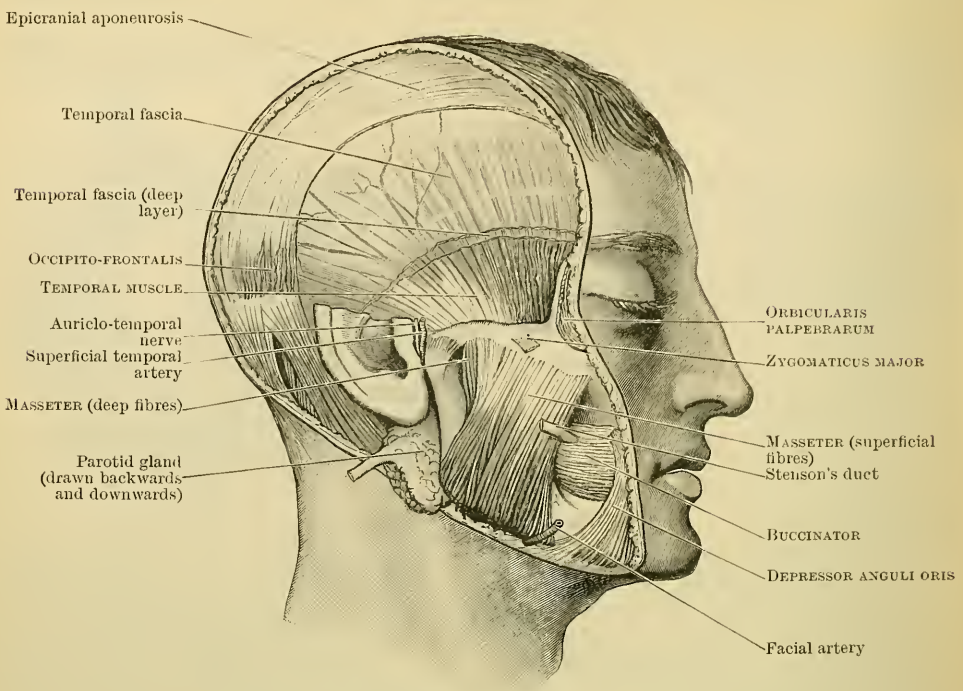


Fig. 320.—Muscles of Mastication (superficial view).

facial nerve. It conceals the lower jaw and a part of the temporal muscle, and is separated from the buccinator muscle anteriorly by a pad of fat.

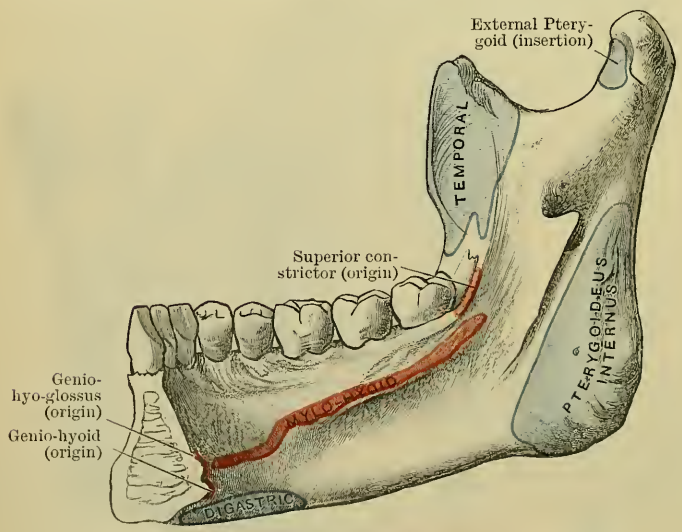


Fig. 321.—Muscle-Attachments on the Inner Side of the Lower Jaw.

The **temporal muscle** is a fan-shaped muscle **arising** from the whole area of the temporal fossa, as well as from the temporal fascia which covers it. Its converging fibres pass beneath the zygomatic arch. In the pterygoid region the muscle is **inserted** into the deep surface and apex of the coronoid process, and into the anterior border of the ramus of the lower jaw (Figs. 319, p. 407, and 321, p. 408).

The muscle is concealed by the temporal fascia, zygoma, the masseter muscle, and the coronoid process. It crosses over the external pterygoid muscle and the internal maxillary artery.

The **external pterygoid muscle arises** by two heads, upper and lower. The upper head is attached to the under surface of the great wing of the sphenoid; the lower head takes origin from the outer surface of the external pterygoid plate. The

muscle is directed outwards and backwards, to be **inserted** into (1) the depression in front of the neck of the lower jaw (Figs. 319, p. 407, and 321, p. 408), and (2) the inter-articular fibro-cartilage and capsule of the temporo-maxillary articulation.

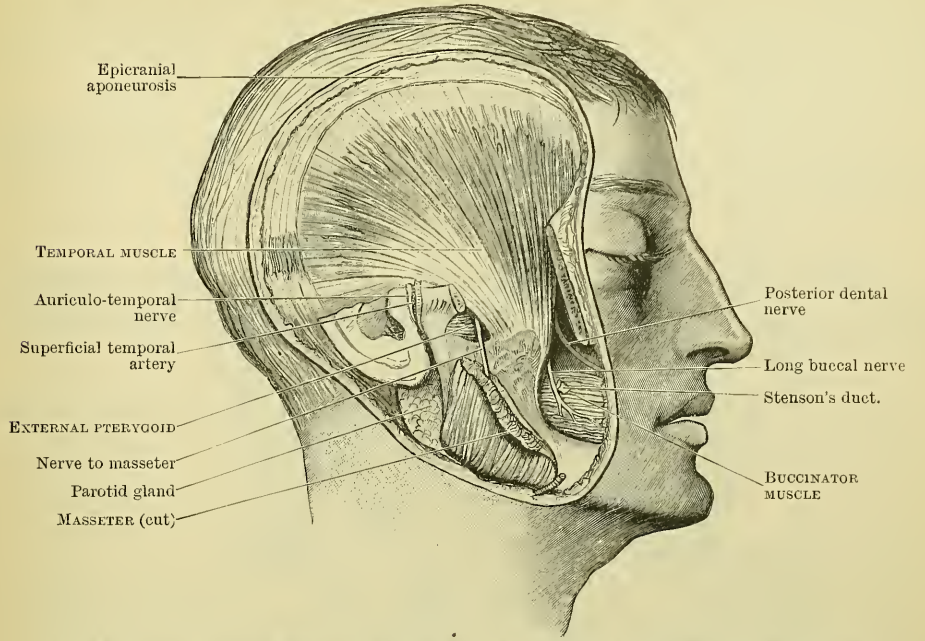


Fig. 322.—Muscles of Mastication, Deeper View (zygoma and masseter muscle removed).

The muscle is placed deeply in the pterygoid region. Covered by the temporal muscle and coronoid process, it partially conceals the internal pterygoid muscle

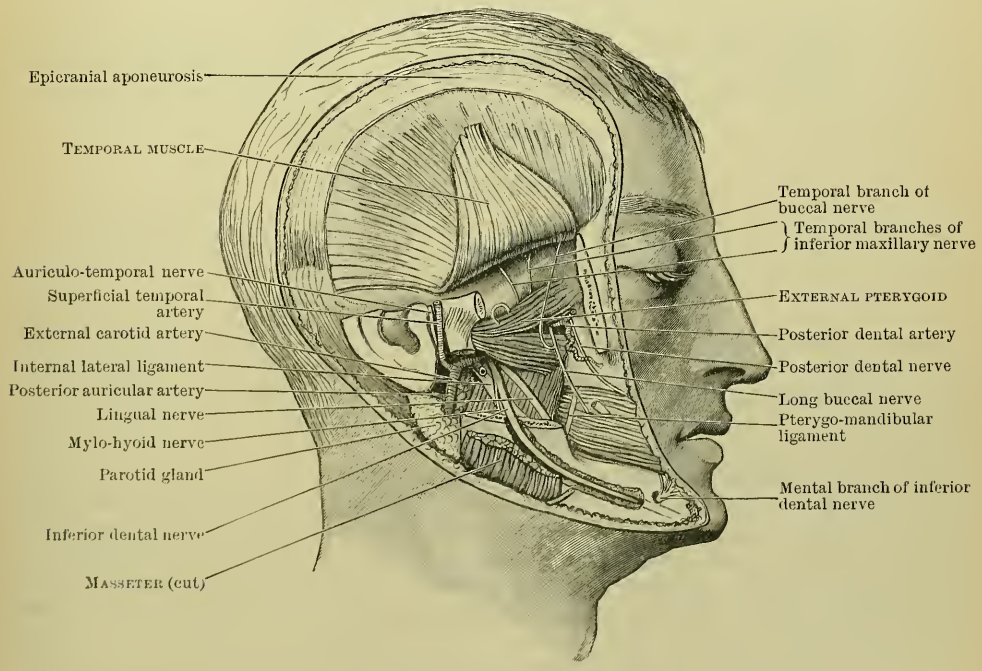


Fig. 323.—Pterygoid Region.

and the trunk and branches of the inferior maxillary nerve. The internal maxillary artery passes over or under the muscle, and disappears between its two heads of origin on its way to the spheno-maxillary fossa.

The **internal pterygoid muscle** has likewise a double **origin**—(1) from the deep surface of the external pterygoid plate and the tuberosity of the palate, and (2) by a stout tendon from the tuberosity of the upper jaw. Its two heads of origin embrace the lower fibres of the external pterygoid muscle. It is quadrilateral in form, and is directed downwards, outwards, and backwards, to be **inserted** into a triangular impression on the inner surface of the lower jaw, between the mylo-hyoid groove and the angle of the bone (Fig. 321, p. 408).

The muscle is covered over by the external pterygoid muscle, by branches of the inferior maxillary nerve, and by the internal lateral ligament and ramus of the lower jaw. Beneath it are the Eustachian tube, muscles of the soft palate, and the pharynx (superior constrictor).

Nerve-Supply.

The **inferior maxillary division of the fifth nerve** supplies all the muscles of mastication except the buccinator, which is supplied by the **facial nerve.** The internal pterygoid muscle is supplied by the nerve before its division into anterior and posterior parts; the other muscles are innervated by the anterior trunk.

Actions.

The above muscles, assisted by others in the neck, produce the various movements of the lower jaw, as follows:—

a. **Opening** and **Closure of the Jaw.**	
Weight of the jaw Digastric Mylo-hyoid Genio-hyoid Genio-hyo-glossus Infra-hyoid muscles	Masseter Temporal Internal pterygoid
b. **Protrusion** and **Retraction.**	
External pterygoid Internal pterygoid Temporal (*anterior fibres*)	Temporal (*posterior fibres*)
c. **Lateral Movement of the Jaw.**	
External pterygoid } (*of one side*) Internal „ }	

THE MUSCLES OF THE NECK.

The muscles in the neck include, in addition to those included in the description of the muscles of the back (p. 395), the following series: (1) sterno-cleido-mastoid; (2) the muscles of the hyoid bone (supra-hyoid and infra-hyoid); (3) the muscles of the tongue (extrinsic and intrinsic); (4) the muscles of the pharynx and soft palate; and (5) the prævertebral muscles.

The **sterno-cleido-mastoid muscle** is the prominent muscle projecting on the side of the neck. It **arises** by two heads—(1) a narrow tendinous *sternal* head, from the anterior surface of the manubrium sterni (Fig. 246, p. 322), and (2) a broader *clavicular* origin, partly tendinous, partly fleshy, from the upper surface of the clavicle in its inner third (Fig. 243, p. 319). The muscle is **inserted** into the outer surface of the mastoid process and into the superior curved line of the occipital bone (Fig. 324, p. 411).

The sterno-cleido-mastoid muscle stretches obliquely across the neck, and separates the anterior and posterior triangles from one another. Superficially it is covered by the platysma myoides muscle, the external jugular vein, and some of the superficial branches of the cervical plexus. It conceals the splenius capitis, digastric, levator anguli scapulæ, scaleni and infra-hyoid muscles, the carotid

sheath, the cervical plexus, and the spinal accessory nerve. The last-named nerve pierces the muscle.

The sterno-cleido-mastoid muscle is properly divisible into three parts: (1) **sterno-mastoid**, placed superficially, and passing obliquely from the sternum to the mastoid process; (2) **cleido-mastoid**, placed more deeply, and directed vertically upwards from the clavicle to the mastoid

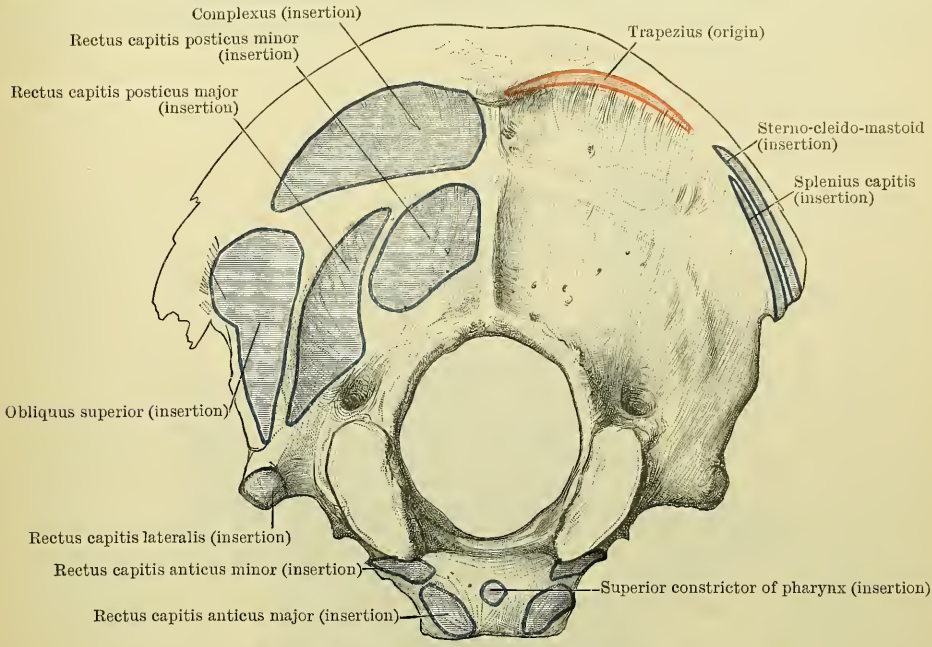


FIG. 324.—MUSCLE-ATTACHMENTS TO OCCIPITAL BONE (Inferior Surface).

process; and (3) **cleido-occipitalis**, passing obliquely upwards and backwards behind the cleido-mastoid to the superior curved line of the occipital bone.

The sterno-mastoid muscle is innervated by the spinal accessory nerve, joined by a branch from the cervical plexus (C. 2).

The action of the muscle is referred to below.

THE MUSCLES OF THE HYOID BONE.

The muscles attached to the hyoid bone are in three series: (1) infra-hyoid muscles, connecting the hyoid bone to the scapula, thorax, and thyroid cartilage; (2) supra-hyoid muscles, connecting it to the lower jaw, cranium, and tongue; and (3) the middle constrictor muscle of the pharynx.

The **infra-hyoid muscles** comprise the omo-hyoid, sterno-hyoid, sterno-thyroid, and thyro-hyoid muscles.

The **omo-hyoid** is a muscle with two bellies, anterior and posterior. The *posterior* belly **arises** from the superior border of the scapula and the suprascapular ligament (Fig. 250, p. 325). It forms a narrow muscular band, which is directed obliquely forwards and upwards, to end in an intermediate tendon beneath the sterno-mastoid muscle. From this tendon the anterior belly proceeds upwards to be **inserted** into the outer part of the lower border of the body of the hyoid bone.

The posterior belly of the muscle separates the posterior triangle into occipital and subclavian parts; the anterior belly crosses the common carotid artery at the level of the cricoid cartilage, and in the anterior triangle forms the boundary between the muscular and carotid triangles. A process of the deep cervical fascia binds down the tendon and the posterior belly to the scapula and the first rib.

The **sterno-hyoid muscle** arises from the posterior surface of the presternum, from the back of the first costal cartilage, and from the clavicle (Fig. 243, p. 319). It passes vertically upwards in the neck, internal to the omo-hyoid and in front of the sterno-thyroid muscle, to be **inserted** into the inner part of the body of the

hyoid bone. Except near its origin the muscle lies superficially in the anterior triangle, alongside the omo-hyoid and in front of the sterno-thyroid and thyro-hyoid muscles, the trachea and the thyroid body.

The **sterno-thyroid muscle arises** beneath the sterno-hyoid from the back of the presternum and first costal cartilage. Broader than the preceding muscle, it passes upwards and slightly outwards in the neck in front of the trachea and thyroid body, and beneath the omo-hyoid and sterno-hyoid muscles, to be **inserted**

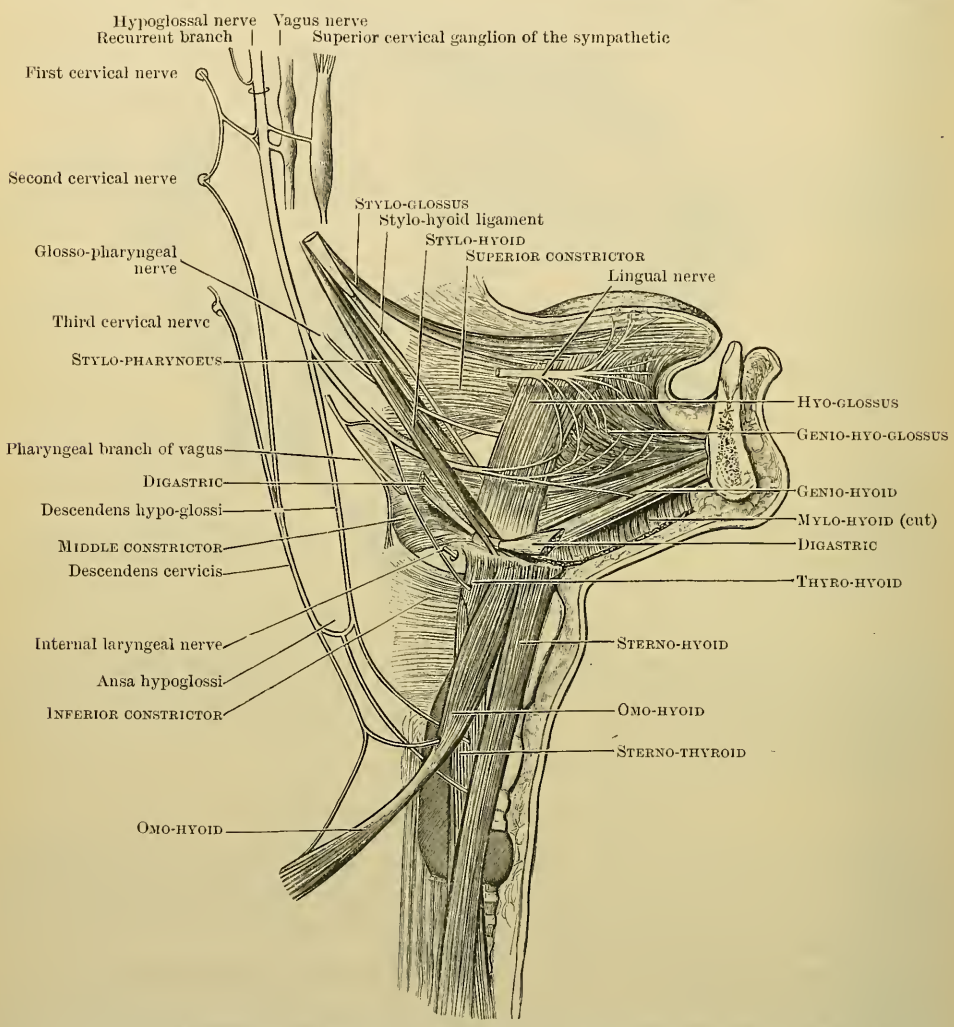


Fig. 325.—The Muscles of the Hyoid Bone and Styloid Process, and the Extrinsic Muscles of the Tongue, with their Nerves.

into the oblique line of the thyroid cartilage. The muscle is marked by an oblique tendinous intersection in the middle of its length.

The **thyro-hyoid muscle** continues the line of the preceding muscle to the hyoid bone. Short and quadrilateral, it **arises** from the oblique line of the thyroid cartilage, and passing over the thyro-hyoid membrane beneath the omo-hyoid and sterno-hyoid, it is **inserted** into the body and great cornu of the hyoid bone.

The **levator glandulæ thyroideæ** is an occasional slip stretching between the hyoid bone and the isthmus or pyramid of the thyroid body.

The **supra-hyoid muscles** comprise the digastric, stylo-hyoid, mylo-hyoid, genio-hyoid muscles, and also two muscles, the genio-hyo-glossus and hyo-glossus, which will be described along with the extrinsic muscles of the tongue.

The **digastric muscle**, as its name implies, possesses two bellies—anterior and posterior. The posterior belly arises from the digastric groove beneath the mastoid process. It is directed forwards and downwards to end in an intermediate tendon, which is connected by a pulley-like band of cervical fascia to the body of the hyoid bone. The anterior belly of the muscle is directed forwards and upwards to the chin, and is **inserted** into an oval impression on the lower border of the mandible close to the symphysis (Fig. 327, p. 414). The muscle forms the boundary of the submaxillary space. The posterior belly is concealed at its origin by the mastoid

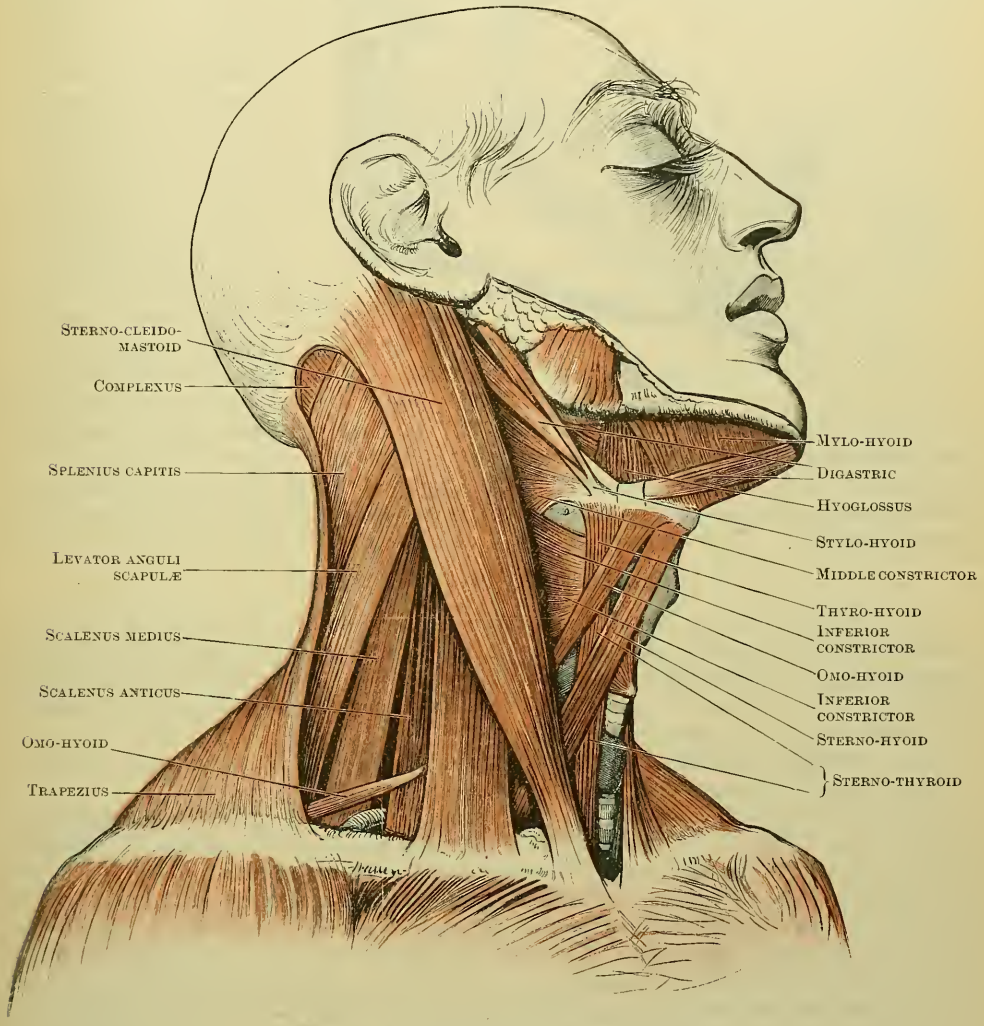


Fig. 326.—The Triangles of the Neck (Muscles).

process and the muscles attached to it. In company with the stylo-hyoid muscle it crosses the carotid vessels and the hypoglossal nerve in the anterior triangle. The anterior belly of the digastric covers the mylo-hyoid muscle.

The **stylo-hyoid muscle arises** from the styloid process of the temporal bone near its base, and is **inserted** into the body of the hyoid bone by two slips which enclose the tendon of the digastric muscle. It is directed downwards and forwards alongside the posterior belly of the digastric, and crosses the anterior triangle in front of the carotid vessels.

The **mylo-hyoid muscle arises** from the lower three-fourths of the mylo-hyoid ridge of the lower jaw (Fig. 327, p. 414). It is directed downwards and inwards, to be **inserted** into (1) the upper border of the body of the hyoid bone, and more

anteriorly (along with the opposite muscle) into (2) a median raphe extending from the hyoid bone nearly to the chin. The muscle forms a diaphragm in the floor of the mouth, and has in contact with its superficial or external surface the digastric muscle and the submaxillary gland. Its deep or internal surface is partially covered by the mucous membrane of the floor of the mouth, and is separated from the hyo-glossus and genio-hyo-glossus muscles by the deep part of the submaxillary gland, the sublingual gland, Wharton's duct and the lingual and hypoglossal nerves.

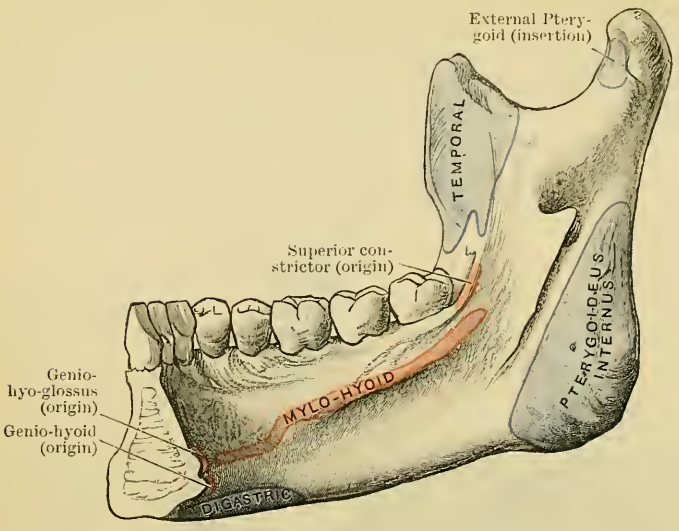


FIG. 327.—MUSCLE-ATTACHMENTS ON THE INNER SIDE OF THE LOWER JAW.

The **genio-hyoid muscle arises** from the lower of the two genial tubercles on the back of the symphysis of the lower jaw (Fig. 327, p. 414). It is directed downwards and backwards, to be **inserted** into the front of the body of the hyoid bone. The muscle lies along the lower border of the genio-hyoglossus, and is concealed by the digastric and mylo-hyoid muscles. The muscles of opposite sides are often fused together.

THE MUSCLES OF THE TONGUE.

The muscular substance of the tongue consists of two symmetrical series of muscles placed on either side of a membranous raphe in the middle line. It is composed of (1) **extrinsic muscles** arising from the soft palate, styloid process, hyoid bone and lower jaw, and (2) **intrinsic muscles** proper to the tongue itself. Each set consists of four series of muscles.

The **extrinsic muscles** are four in number: (1) genio-hyo-glossus, (2) hyo-glossus, (3) stylo-glossus, and (4) palato-glossus.

The **genio-hyo-glossus muscle** (Fig. 325) is an extrinsic muscle of the tongue as well as a supra-hyoid muscle. It is a fan-shaped muscle **arising** by its apex from the upper of the two genial tubercles behind the symphysis of the lower jaw (Fig. 327, p. 414). From this origin the muscular fibres diverge; the lowest fibres are directed downwards and backwards, to be **inserted** into the body of the hyoid bone; the highest fibres curve forwards, to be attached to the tip of the tongue; the intermediate fibres are attached to the substance of the tongue in its whole length between the base and tip. The muscles of opposite sides are separated by the median raphe of the tongue. On the outer side of each are the hyo-glossus and mylo-hyoid muscles. Between the hyo-glossus and genio-hyo-glossus are placed the stylo-hyoid ligament, the lingual artery, and the glosso-pharyngeal nerve.

The **hyo-glossus muscle** is also an extrinsic muscle of the tongue as well as a supra-hyoid muscle. It **arises** from the hyoid bone (body and great cornu), and is directed upwards and forwards, to be **inserted** into the side of the tongue, its fibres interlacing at its insertion with the fibres of the stylo-glossus. The muscle is quadrilateral, and lies between the genio-hyo-glossus and mylo-hyoid muscles, separated from the latter by the mucous membrane of the floor of the mouth, the sublingual and part of the submaxillary glands, the lingual and hypoglossal nerves, and Wharton's duct.

The **chondro-glossus** is a small separated slip of the hyo-glossus, not always present.

The **stylo-glossus muscle arises** beneath the parotid gland from the lower end

of the styloid process and from the stylo-mandibular ligament. It sweeps forwards and inwards, and is **inserted** into the side and under surface of the tongue, its fibres spreading out to decussate with those of the palato-glossus and hyo-glossus muscles. It is covered by the internal pterygoid muscle and by the mucous membrane of the tongue.

The **palato-glossus** is a thin sheet of muscular fibres **arising** from the under surface of the soft palate, where it is continuous with fibres of the opposite muscle. It passes downwards in the anterior pillar of the fauces, and spreads out, to be **inserted** into the sides of the tongue, blending with the stylo-glossus and the deep transverse fibres of the tongue. The muscle is placed directly beneath the mucous membrane of the soft palate and tongue.

Intrinsic Muscles of the Tongue.—Besides receiving the fibres of insertion of the extrinsic muscles, the substance of the tongue is composed of four intrinsic muscles on either side, two in the sagittal plane, the superior and inferior linguales; two in the coronal plane, the transverse and vertical fibres.

The **superior lingualis muscle** extends from base to tip of the tongue, placed on its dorsum immediately under the mucous membrane, into which many of its fibres are inserted.

The **inferior lingualis** is a cylindrical band of muscular fibres occupying the under part of the organ on each side, in the interval between the genio-hyo-glossus and the hyo-glossus muscles. Posteriorly some of its fibres extend to the hyoid bone.

The **transverse fibres** arise from the median raphe, and radiate outwards to the dorsum and sides of the tongue, decussating with the extrinsic muscles and the fibres of the vertical muscle. They occupy the substance of the tongue between the superior and inferior linguales.

The so-called **vertical fibres** arise from the dorsal surface of the tongue, and sweep downwards and outwards to its sides, intermingled with the fibres of the previous muscle and the insertions of the extrinsic muscles. These two muscles form a very considerable part of the total muscular substance of the organ.

Nerve-Supply.

The muscles of the hyoid bone and of the tongue are for the most part supplied by the **ansa cervicalis** (C. 1. 2. 3.) and by the **hypoglossal nerve.** A few of the muscles are supplied by the trigeminal, facial, and spinal accessory nerves.

Muscles.	Nerves.	Origin.
Omo-hyoid Sterno-hyoid Sterno-thyroid	Ansa cervicalis	C. 1. 2. 3.
Thyro-hyoid Genio-hyoid Genio-hyo-glossus Hyo-glossus Stylo-glossus Intrinsic muscles of tongue	Hypoglossal	C. 1. 2. Hypoglossal.
Palato-glossus	Pharyngeal plexus	Spinal accessory.
Mylo-hyoid Digastric Anterior belly	Mylo-hyoid branch of inferior dental nerve	Trigeminal.
Posterior belly Stylo-hyoid	Facial	Facial.

Actions.

These muscles have a complexity of action, owing to their numerous attachments to more or less movable points. The movements for which they are responsible in whole or part are (1) movements of the hyoid bone in mastication and deglutition, (2) movements of the thyroid cartilage, (3) movements of the tongue, (4) movements of the head, (5) movements of the shoulder, and (6) respiration.

(1) **Movements of the Hyoid Bone.**—The hyoid bone is elevated or depressed, and moved

forwards or backwards along with the lower jaw and tongue, in speech, mastication, and swallowing.

a. **Elevation** and **Depression.**		*b.* **Protraction** and **Retraction.**	
Digastric	Thyro-hyoid	Genio-hyoid	Stylo-hyoid
Stylo-hyoid	Sterno-hyoid	Genio-hyo-glossus	Middle constrictor
Mylo-hyoid	Omo-hyoid		
Genio-hyoid	Sterno-thyroid		
Genio-hyo-glossus			
Hyo-glossus			
Muscles closing the mouth			

(2) **Movements of the Thyroid Cartilage.**—The thyroid cartilage is raised and lowered during speech and deglutition.

Elevation.	**Depression.**
Thyro-hyoid	Sterno-thyroid
Stylo-pharyngeus	Crico-thyroid
Palato-pharyngeus	Depressors of hyoid bone
Elevators of hyoid bone	
Muscles closing mouth	

(3) **Movements of the Tongue.**—The chief movements of the tongue in speech and deglutition are elevation and depression, protrusion and retraction, and lateral movements.

a. **Elevation** and **Depression.**	
Stylo-glossus (base)	Genio-hyo-glossus
Palato-glossus	Hyo-glossus
Muscles elevating hyoid bone	Chondro-glossus
Muscles closing mouth	Muscles depressing the hyoid bone

b. **Protrusion** and **Retraction.**	
Genio-hyo-glossus (*posterior fibres*)	Genio-hyo-glossus (*anterior fibres*) Stylo-glossus
c. **Lateral Movements.**—The muscles of one side only.	

(4) **Movements of the Head.**—The sterno-mastoid muscles, acting together, flex the head on the spinal column, assisted by the supra-hyoid and infra-hyoid muscles. The sterno-mastoid muscle of one side, acting alone, bends the head to the same side, and simultaneously rotates it to the opposite side, as seen in *torticollis* (wryneck).

(5) **Movements of the Shoulder Girdle.**—The omo-hyoid and sterno-mastoid muscles have already been included among the elevators of the shoulder girdle.

(6) **Respiration.**—The muscles in the front of the neck are auxiliary muscles in extraordinary or difficult inspiration. The masseter and temporal muscles fix the lower jaw; the hyoid bone is raised and fixed by the supra-hyoid muscles; and the sternum is raised by the sterno-mastoid and infra-hyoid muscles.

The Muscles of the Pharynx.

The muscular envelope of the pharynx is composed of two strata. The *external* or *circular layer* consists of the three constrictor muscles; the *internal* or *longitudinal layer* consists of the fibres of the stylo-pharyngeus and palato-pharyngeus muscles.

The **superior constrictor muscle** is triangular or fan-shaped. It arises successively from the lower half of the posterior border of the internal pterygoid plate, from the pterygo-mandibular ligament, from the mylo-hyoid ridge of the

lower jaw (Fig. 327, p. 414), and from the mucous membrane of the floor of the mouth (*glosso-pharyngeus*). The muscular fibres radiate backwards, and are **inserted** for the most part into a median raphe extending down the back wall of the pharynx in the middle line. The highest fibres are attached to the pharyngeal spine of the occipital bone (Fig. 333, p. 421), and the lowest fibres are overlapped by the middle constrictor. A crescentic interval occurs above the muscle, below the base of the skull, in which the Eustachian tube and the levator and tensor palati muscles appear. Its lower border is separated from the middle constrictor by the stylo-pharyngeus muscle and the glosso-pharyngeal nerve. The superior constrictor muscle separates the internal carotid artery from the cavity of the pharynx and tonsil.

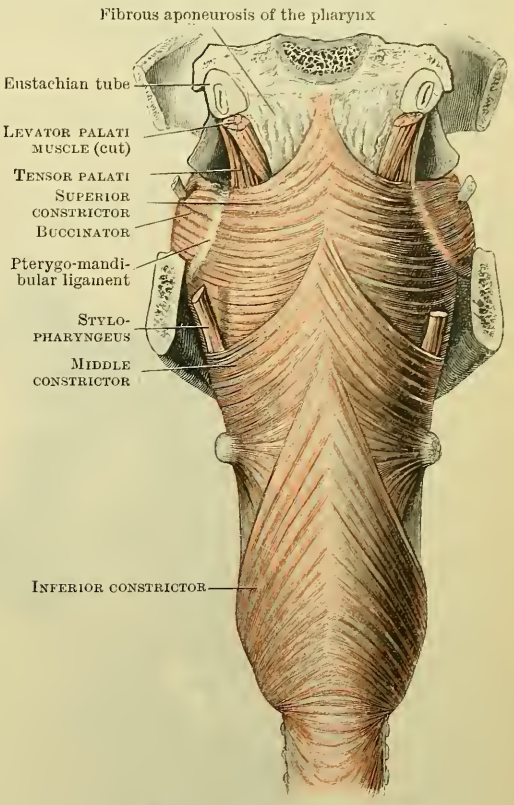


Fig. 328.—Posterior View of the Pharynx and Constrictor Muscles.

The **middle constrictor muscle arises** from the stylo-hyoid ligament and from both cornua of the hyoid bone. From its origin the muscular fibres radiate backwards, to be **inserted** into the median raphe on the posterior aspect of the pharynx. The upper fibres overlap the lower part of the superior constrictor; the lower fibres are concealed from view by the inferior constrictor muscle. In the interval between the middle and inferior constrictors are found the internal laryngeal artery and nerve.

The **inferior constrictor muscle arises** from the oblique line of the thyroid cartilage, and from the side of the cricoid cartilage. Its fibres radiate backwards, to be **inserted** into the median raphe on the back of the pharynx, the upper fibres overlapping the lower part of the middle constrictor, the lower fibres blending with the muscular fibres of the œsophagus. Below the lower border of the muscle the inferior laryngeal artery and nerve enter into relation with the larynx.

The **deeper longitudinal stratum** of muscles in the pharyngeal wall is composed of the insertions of the stylo-pharyngeus and palato-pharyngeus muscles.

The **stylo-pharyngeus arises** from the root of the styloid process on its inner side, and passes downwards between the external and internal carotid arteries. It enters the wall of the pharynx in the interval between the superior and middle constrictor muscles. Spreading out beneath the middle constrictor muscle, it is **inserted** into the superior and posterior borders of the thyroid cartilage and into the wall of the pharynx itself, becoming continuous posteriorly with the palato-pharyngeus. In the neck the glosso-pharyngeal nerve winds round it on its way to the tongue.

The **palato-pharyngeus** occupies the soft palate and the pharyngeal wall. In the substance of the soft palate it consists of two layers, a postero-superior layer, thin, and continuous across the middle line with the corresponding layer on the opposite side, and an antero-inferior layer, which is thicker, and is attached to the posterior border of the hard palate. The levator palati and azygos uvulæ muscles are enclosed between the two layers, which unite at the posterior edge of the palate, receiving at the same time additional fibres arising from the Eustachian tube (*salpingo-pharyngeus*). The muscle descends to the pharynx in the posterior pillar

of the fauces. Its fibres spread out in the form of a thin sheet in the wall of the pharynx, in continuity anteriorly with the stylo-pharyngeus, and are **inserted** into the posterior border of the thyroid cartilage, and behind that into the aponeurosis of the pharynx, reaching down as far as the lower border of the inferior constrictor. The muscle is placed beneath the middle and inferior constrictors in the pharyngeal wall, and the fibres of the muscles of opposite sides decussate in the middle line beneath the median raphe.

The Muscles of the Soft Palate.

The soft palate and uvula form a muscular fold, covered on each surface by mucous membrane, projecting backwards into the pharynx, and forming the posterior part of the roof of the mouth.

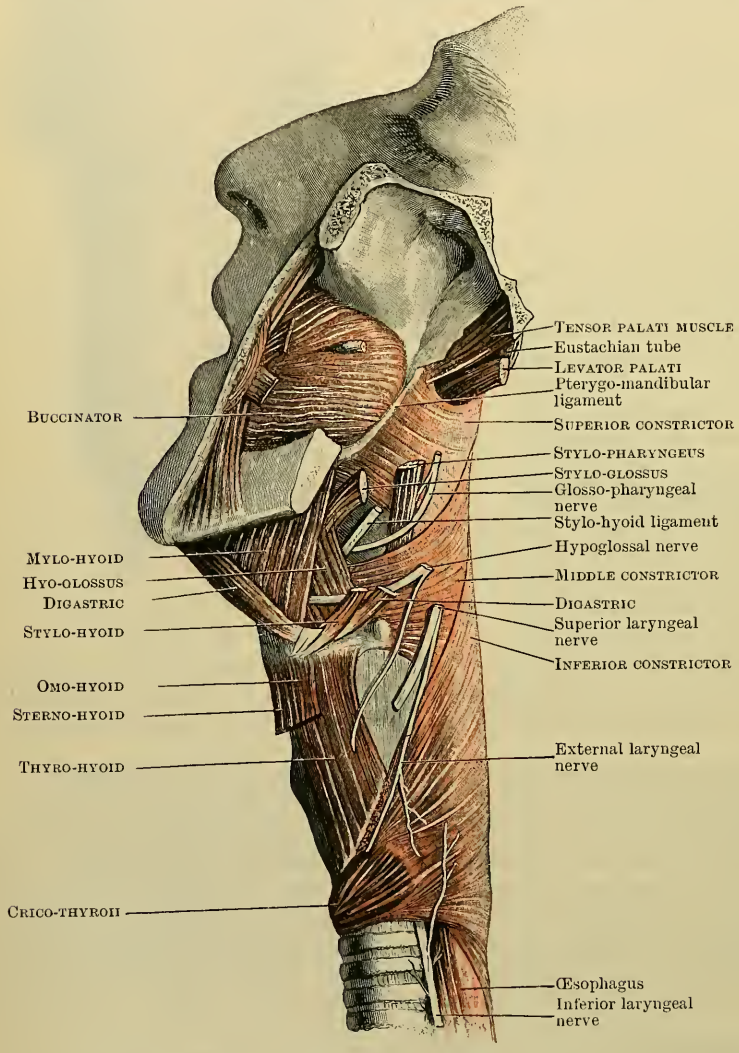


Fig. 329.—Lateral View of the Wall of the Pharynx.

The muscular fold is composed of five pairs of muscles—the palato-pharyngeus (and salpingo-pharyngeus), azygos uvulæ, levator palati, tensor palati, and palato-glossus.

The **palato-pharyngeus** muscle has been already described (p. 417) among the muscles of the pharynx.

The **azygos uvulæ** consists of two narrow bundles enclosed, along with the insertion of the levator palati, between the layers of the palato-pharyngeus. The slips **arise** from the posterior nasal spine and the aponeurosis of the soft palate, and unite as they proceed backwards to end in the uvula.

The **levator palati** has a double **origin**: (1) from the under surface of the apex of the petrous portion of the temporal bone, and (2) from the lower part of the cartilaginous Eustachian tube. It passes obliquely downwards and inwards, across the upper border of the superior constrictor muscle, and enters the soft palate between the two layers of the palato-pharyngeus muscle. It is **inserted** into the aponeurosis of the soft palate, and some of its fibres become continuous with those of the opposite muscle. It is separated from the tensor

palati muscle by the Eustachian tube and the deeper layer of the palato-pharyngeus muscle.

The **tensor (circumflexus) palati** arises (1) from the scaphoid fossa and the alar spine of the sphenoid bone, and (2) from the outer side of the cartilaginous Eustachian tube. It descends between the internal pterygoid muscle and the internal pterygoid plate, and ends in a tendon which hooks round the hamular process, and is **inserted** beneath the levator palati into the posterior border of the hard palate, and into the aponeurosis of the soft palate.

The **palato-glossus muscle,** occupying the under surface of the soft palate and the anterior pillar of the fauces, has already been described with the muscles of the tongue (p. 415).

Nerve-Supply.

The chief nerve supplying the muscles of the pharynx and soft palate is the **spinal accessory nerve,** aided by the **fifth** (otic ganglion) and the **ninth** (glosso-pharyngeal) nerves and the laryngeal branches of the **vagus nerve.**

Muscles.	Nerves.	Origin.
Constrictors of pharynx Palato-glossus Palato-pharyngeus Levator palati Azygos uvulæ	Pharyngeal plexus	XI.
Tensor palati	Otic ganglion	V.
Stylo-pharyngeus	Glosso-pharyngeal	IX.
Inferior constrictor	External laryngeal Inferior laryngeal	X.

Actions.

The muscles of the pharynx and soft palate are chiefly brought into action in **the act of swallowing.** This act is divided into a *voluntary stage,* in which the bolus lies in front of the pillars of the fauces, and an *involuntary stage,* during which the food passes from the mouth through the pharynx. The movements occurring during the passage of food through the mouth are as follows: the cheeks are compressed by the action of the buccinator muscles; the tongue, hyoid bone, and thyroid cartilage are successively raised upwards by the action of the muscles which close the mouth and elevate the hyoid bone. By these means the food is pushed backwards between the pillars of the fauces.

At the same time, by the contraction of the palato-glossus and palato-pharyngeus, the pillars of the fauces are narrowed, while the muscles of the soft palate, contracting, tighten the soft palate, and by bringing it in contact with the posterior wall of the pharynx, shut off the upper (nasal) portion of the cavity. The elevation of the tongue, hyoid bone, and larynx simultaneously causes the elevation of the epiglottis and the aperture of the glottis, which is closed by the approximation of the arytenoid cartilages and the combined action of laryngeal muscles (arytenoideus, thyro-arytenoideus, and thyro-aryteno-epiglottideus). The food thus slips over the posterior surface of the epiglottis and the closed aperture of the glottis, and between the pillars of the fauces on either side, into the pharynx. It is now clasped by the constrictor muscles, which, by their contractions, force it down into the œsophagus. The contraction of the constrictor muscles results in a flattening of the pharynx and elevation of its anterior attachments.

During the act of swallowing, it is generally thought that the Eustachian tube is opened by the contraction of the tensor palati muscle which arises from it. It has been held, on the other hand, that the Eustachian tube is closed during swallowing by the compression of its wall by the contraction of the levator palati.

Deep Lateral and Prævertebral Muscles of the Neck.

Three series of muscles are comprised in this group: (1) vertebro-costal (scaleni, anticus, medius, and posticus), (2) vertebro-cranial (recti capitis antici, major and minor, and lateralis), and (3) vertebral (longus colli).

The **scalenus anticus arises** from the anterior tubercles of the transverse processes of the third, fourth, fifth, and sixth cervical vertebræ, and descends behind the carotid sheath, to be **inserted** into the scalene tubercle and ridge on the first rib (Fig. 330, p. 420). In front of the muscle are the subclavian and internal jugular veins, and the nerves descending through the neck. Behind, it is

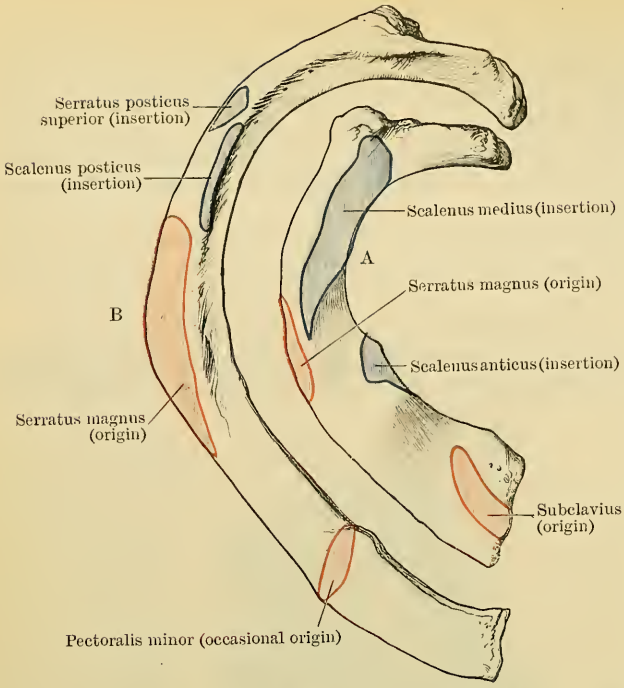


FIG. 330.—MUSCLE-ATTACHMENTS TO THE UPPER SURFACE OF THE FIRST RIB, AND THE OUTER SURFACE OF THE SECOND RIB.

A, First rib; B, Second rib.

and sixth cervical transverse processes, and is **inserted** into a linear impression on the outer side of the second rib. It is concealed behind by the levator anguli scapulæ, and is in contact anteriorly with the scalenus medius.

The **rectus capitis anticus major** arises from the anterior tubercles of the transverse processes of the third, fourth, fifth, and sixth cervical vertebræ. It forms a flat triangular muscle, which is directed upwards, to be **inserted** into an impression on the under surface of the basilar process of the occipital bone in front and to the outer side of the pharyngeal spine (Fig. 333, p. 421). It lies on the cervical vertebræ behind the carotid vessels and the separated from the scalenus medius by the cords of the brachial plexus, the subclavian artery, and the pleura.

The **scalenus medius** arises from the posterior tubercles of the transverse processes of the cervical vertebræ, from the second to the sixth inclusive. It descends in the floor of the posterior triangle, to be **inserted** into the rough impression on the first rib behind the subclavian artery (Fig. 330, p. 420). The muscle is covered anteriorly by the cords of the brachial plexus, the subclavian artery, and the omohyoid muscle, and is in contact behind with the levator anguli scapulæ and the scalenus posticus. It is pierced by the posterior scapular and posterior thoracic nerves.

The **scalenus posticus** arises from the posterior tubercles of the fourth, fifth,

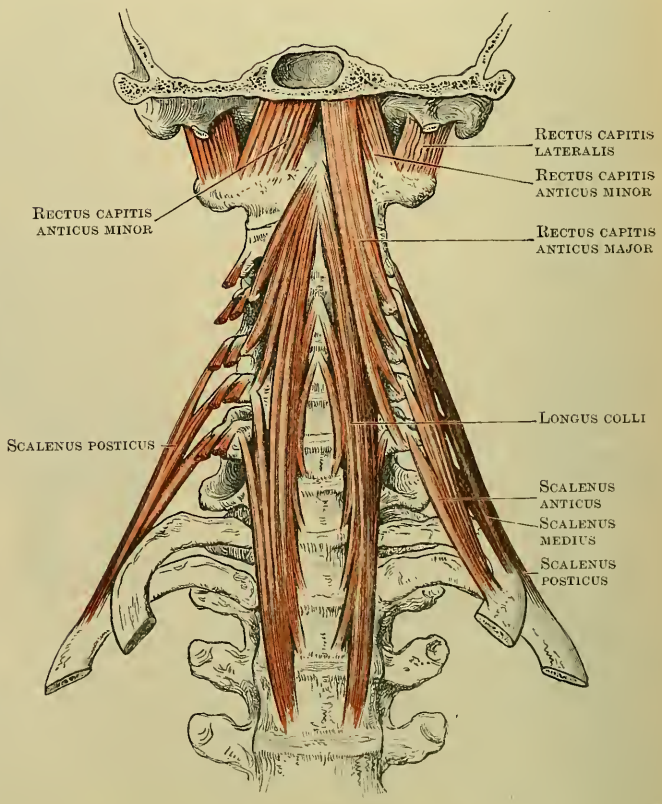


FIG. 331.—THE PRÆVERTEBRAL MUSCLES OF THE NECK.

pharynx, external to the longus colli, and internal at its origin to the scalenus anticus.

The **rectus capitis anticus minor** arises from the anterior arch of the atlas, and

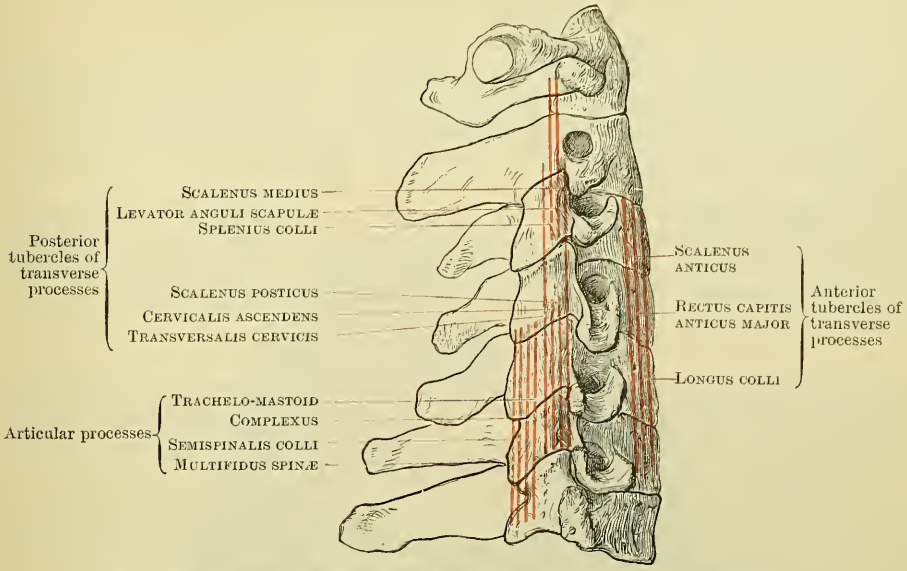


Fig. 332.—Scheme of Muscular-Attachments to Cervical Vertebræ.

is **inserted** into the basilar process between the previous muscle and the occipital condyle (Fig. 333, p. 421). It is concealed by the rectus capitis anticus major.

The **longus colli** is a flattened muscular band extending from the third thoracic

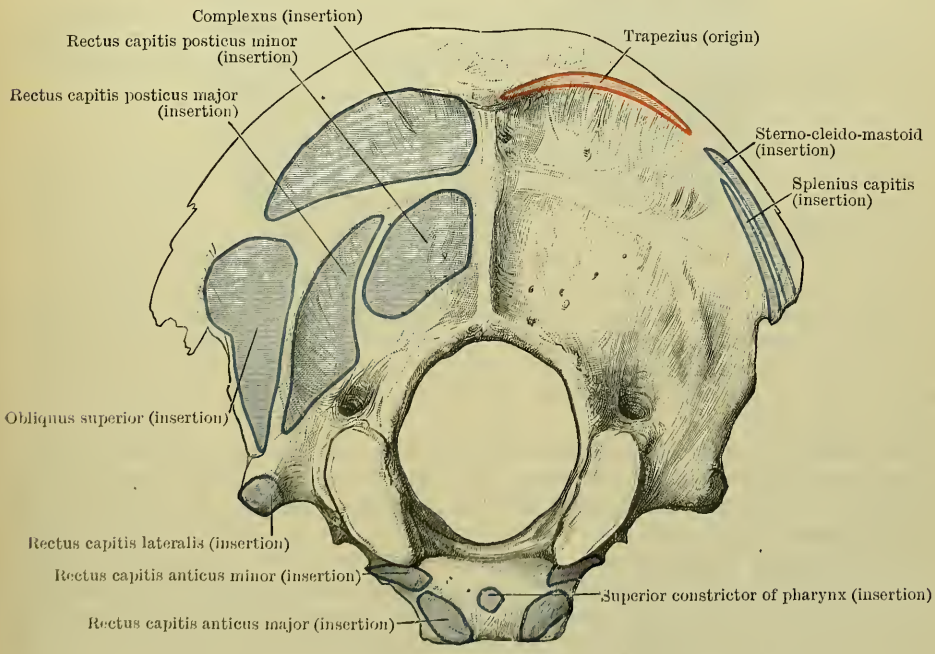


Fig. 333.—Muscle-Attachments to Occipital Bone (Inferior Surface).

vertebra to the atlas. It is divisible into three portions—a vertical, a lower oblique, and an upper oblique portion.

The **vertical portion** of the muscle arises from the bodies of the first three

thoracic and the last three cervical vertebræ; and passing vertically upwards, it is **inserted** into the bodies of the second, third, and fourth cervical vertebræ.

The **lower oblique portion arises** from the bodies of the first three thoracic vertebræ, and is **inserted** into the anterior tubercles of the fifth and sixth cervical vertebræ.

The **upper oblique portion arises** from the anterior tubercles of the transverse processes of the third, fourth, and fifth cervical vertebræ, and is directed upwards, to be **inserted** into the anterior tubercle of the atlas.

The longus colli muscle clothes the front of the vertebral column in the neck, and is separated by the deep cervical fascia from the carotid vessels, pharynx, and œsophagus.

The **rectus capitis lateralis**, in series with the posterior inter-transverse muscles in the neck, **arises** from the transverse process of the atlas, and is **inserted** into the under surface of the ex-occipital bone. It is placed alongside the recti capitis antici, separated from them by the anterior primary division of the first cervical nerve.

Nerve-Supply.

The prævertebral muscles are all supplied by anterior primary divisions of the **cervical spinal nerves**: the rectus capitis anticus minor, and rectus capitis lateralis, by the loop between the first two nerves; the rectus capitis anticus major by the first four; the longus colli by the second, third, and fourth; the scaleni by the lower four or five cervical nerves.

Actions.

The movements produced by these muscles are considered along with those of other muscles acting on the head, spinal column, and thorax (pp. 398, 426).

THE MUSCLES OF THE THORAX.

Muscles of Respiration.

The muscles which complete the boundaries of the thorax are the diaphragm and intercostal muscles (external and internal), along with three series of smaller muscles—the triangularis sterni, the levatores costarum, and the infra-costales.

The **intercostal muscles** are arranged in eleven pairs, forming thin layers filling up the intercostal spaces.

Each **external muscle arises** from the sharp lower border of a rib, and is directed downward and forward, to be **inserted** into the outer edge of the upper border of the rib below. It extends from the tubercle of the rib behind nearly to the costal cartilage in front. The *anterior intercostal aponeurosis* is continuous with it anteriorly, and extends forwards to the side of the sternum.

Each **internal muscle arises** from the costal cartilage and the inner edge of the subcostal groove, and is directed downwards and backwards, to be **inserted** into the inner edge of the upper border of the rib and costal cartilage below. It extends from the side of the sternum in front to the angle of the rib behind, where it becomes continuous with the *posterior intercostal aponeurosis* extending to the tubercle of the rib.

The external intercostal muscles are covered by the pectoral muscles, serratus magnus, and the muscles of the back; the internal muscles are in contact with the pleura. The intercostal vessels and nerve lie between the two muscles in the posterior part of the thorax.

The **levatores costarum** are in series with the external intercostal muscles. They are twelve small slips **arising** from the transverse processes of the seventh cervical and upper eleven thoracic vertebræ. They spread out in a fan-like manner as they descend, to be **inserted** into the outer surface of the ribs posterior to the angles. They lie under cover of the longissimus dorsi muscle.

The **infra-costales** (subcostales) are slips of muscles found on the inner surface of the lower ribs near their angles. They are in series with the internal intercostal muscles, but pass over the deep surface of several ribs.

The **triangularis sterni** (m. transversus thoracis) occupies the posterior aspect

of the anterior thoracic wall. It **arises** from the back of the ensiform cartilage and mesosternum as high as the level of the third costal cartilage. From this origin its fibres radiate outwards, the lower ones horizontally, the upper ones obliquely upwards, to be **inserted** into the costal cartilages of all the true ribs except the first and seventh. The muscle lies against the pericardium and pleura. It is separated from the chest wall by the internal mammary vessels and the anterior branches of the intercostal nerves. The muscle is continuous below with the transversalis abdominis.

The **diaphragm** is the great membranous and muscular partition separating the cavities of the thorax and abdomen. It forms a thin lamella arching over

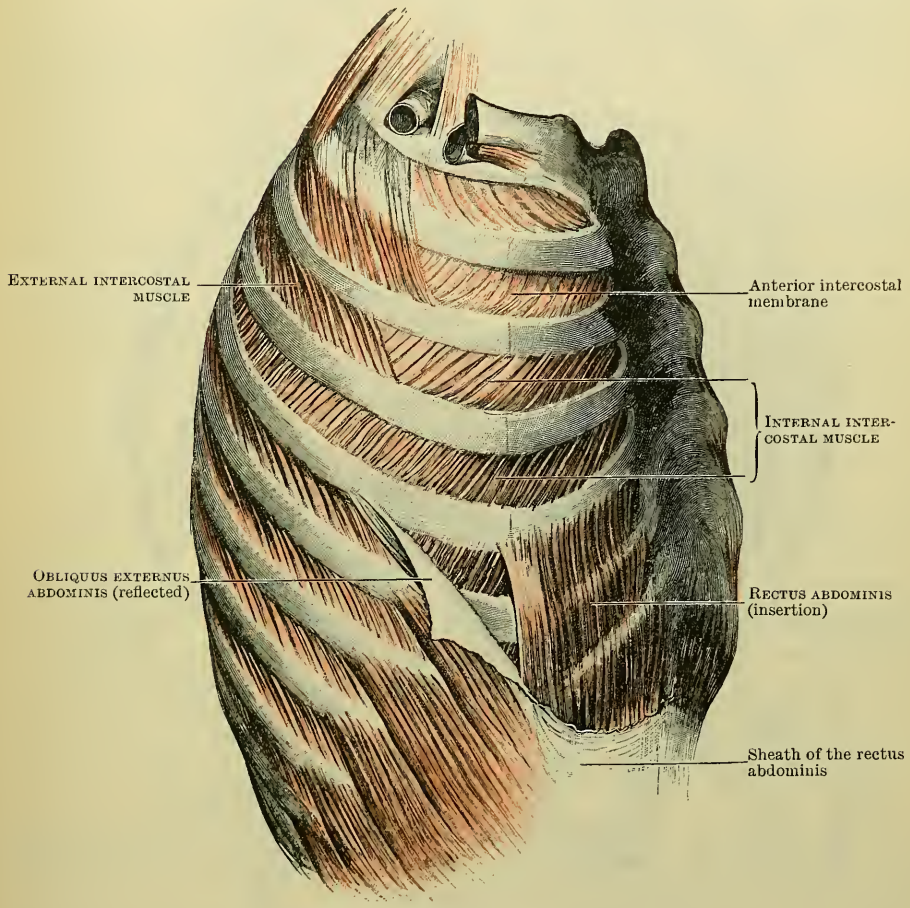


Fig. 334.—The Muscles of the Thoracic Wall.

the liver, stomach, and spleen, with its convex upper surface in contact with the pericardium, pleuræ, and chest wall. It possesses a peripheral origin from the sternum, ribs, and vertebral column, and an insertion into a central tendon. It **arises** (1) *anteriorly* from the posterior surface of the ensiform cartilage by two slender fleshy slips, directed backwards; (2) *laterally*, from the deep surface of the lower six rib-cartilages on each side by fleshy bands which interdigitate with those of the transversalis abdominis; (3) *posteriorly*, from the lumbar vertebræ, by the crura, and from the arcuate ligaments. The **crura** are two elongated fibro-muscular bundles which arise from the front of the bodies of the lumbar vertebræ, on the right side from the first three, on the left side from the first two vertebræ. They are directed upwards and, passing in front of the aorta, decussate across the middle line in front of that vessel, the fibres of the right crus passing in front of those of the left crus. The fibres then encircle the œsophagus, forming an elliptical opening

for its passage, and finally join the central tendon, after a second decussation in front of the gullet.

The **arcuate ligaments** are five in number.

The **middle arcuate ligament** is a fibrous arch connecting together the crura of the diaphragm in front of the aorta, and giving origin to fibres which join the crura as they decussate to encircle the gullet.

The **internal arcuate ligament** is a thickening formed by the attachment of the psoas fascia to the body of the first lumbar vertebra internally and its transverse process externally. Stretching across the upper end of the psoas muscle, the ligament gives origin to muscular fibres directed upwards on each side of the crura.

The **external arcuate ligament** is the thickened upper end of the fascia over the quadratus lumborum (anterior layer of the lumbar fascia), and is attached internally to the transverse process of the first lumbar vertebra, and externally to the

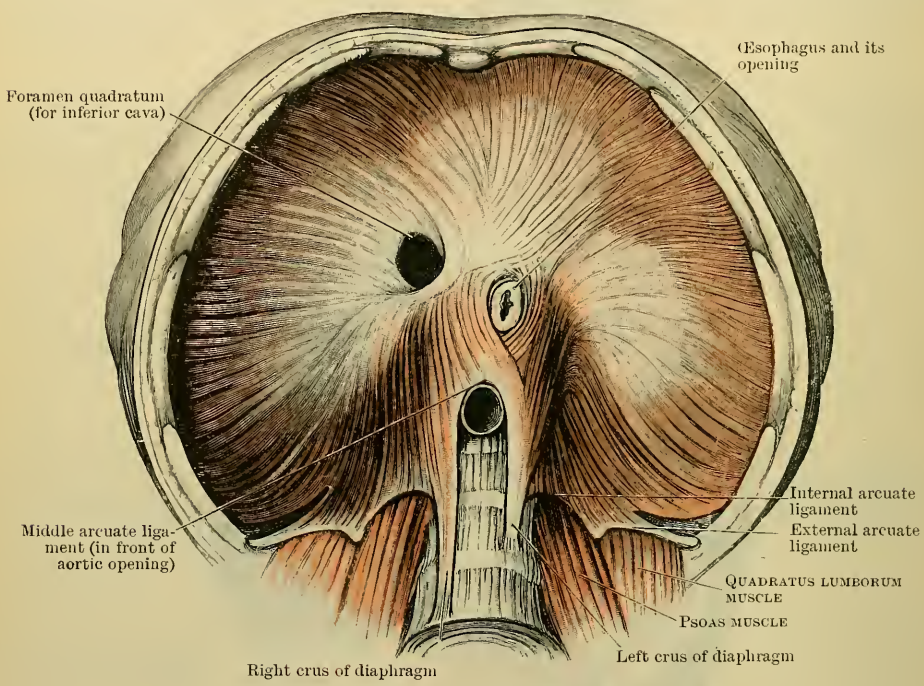


Fig. 335.—The Diaphragm (from below).

last rib. It gives origin to another broad band of muscular fibres, separated from those arising from the internal arcuate ligament by an interval, and passing upwards to the central tendon of the diaphragm.

From this extensive origin the muscular fibres of the diaphragm converge to an **insertion** into a large trilobed **central tendon.** Of its lobes the right one is the largest, the middle or anterior is intermediate in size, and the left is the smallest. It does not occupy the centre of the muscle, being placed nearer the front than the back. The fibres of the crura are consequently the longest; those from the sternum are the shortest.

The diaphragm is pierced by numerous structures. The superior epigastric artery enters the sheath of the rectus abdominis between its sternal and costal origins; the musculo-phrenic artery passes between its attachments to the seventh and eighth ribs. The sympathetic cord and the splanchnic nerves pierce or pass behind the diaphragm; the last thoracic nerve passes beneath the external arcuate ligament; and the aorta, the vena azygos major, and thoracic duct pass between the crura, underneath the middle arcuate ligament (*aortic opening*). The special foramina are two in number. The *foramen quadratum* in the right lobe of the central tendon transmits the inferior vena cava, and small branches of the right

phrenic nerve. The *œsophageal opening* is in the muscular substance of the diaphragm, behind the central tendon, and is surrounded by a sphincter-like arrangement of the crural fibres. Besides the œsophagus, this opening transmits the two pneumogastric nerves. The upper convex surface of the diaphragm forms the sloping floor of the thorax, and is in contact with the pleuræ and the pericardium (which is firmly bound down to the central tendon, and less firmly to the

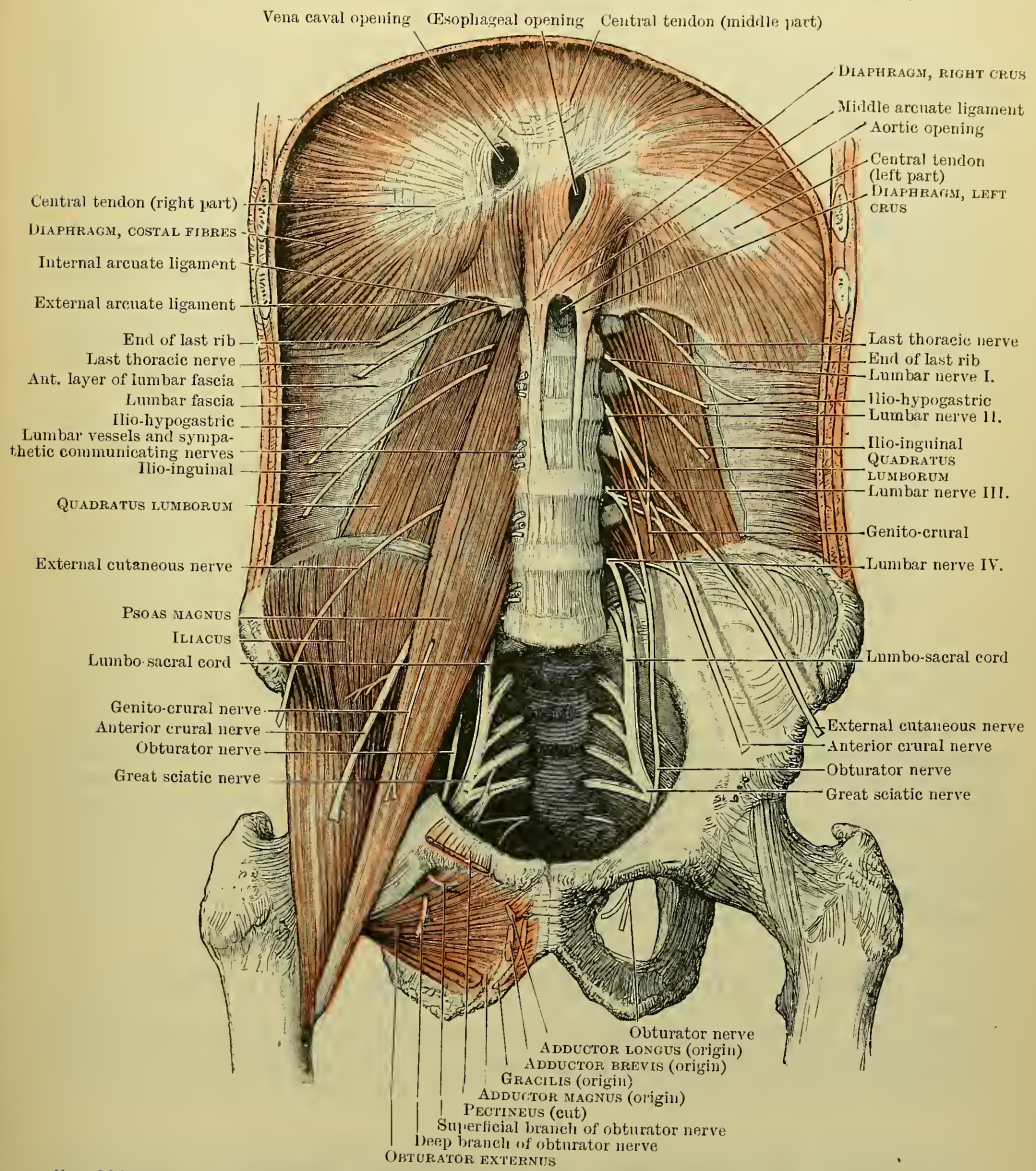


Fig. 336.—View of the Posterior Abdominal Wall, to show the Muscles and the Nerves of the Lumbo-Sacral Plexus.

muscular fibres on the left side). By its lateral margins the diaphragm is in contact on each side with the thoracic wall beyond the reflection of the pleura, and behind with the œsophagus and descending thoracic aorta. The under surface of the diaphragm is concave, and is for the most part invested by peritoneum. It is in relation with the liver, stomach, spleen, kidneys, suprarenal bodies, duodenum and pancreas, the inferior vena cava, and the branches of the cœliac axis. Its vault is higher on the right side than on the left, owing to the upward projection of the liver on that side.

The diaphragm is found as a complete septum between the thorax and abdomen only in mammals. It is occasionally deficient in the human subject, producing *hernia of the diaphragm*, either into the pericardial cavity through the central tendon, or into the thoracic cavity through the lateral portions of the muscle. A rare condition is congenital deficiency of a part of the lateral half of the muscle, generally placed posteriorly, and on the left side. This produces, by continuity of the peritoneum and pleura behind the diaphragm, a *congenital diaphragmatic hernia.*

Nerve-Supply.

The intercostal muscles, levatores costarum, infra-costal muscles, and triangularis sterni, are all supplied by the anterior primary divisions of the **intercostal nerves.** The diaphragm receives its chief, if not its entire, motor supply from the **phrenic nerves** (C. 3. 4. 5.) It is innervated also by the diaphragmatic plexus of the sympathetic, and is said to receive fibres from the lower intercostal nerves.

Actions.

The act of respiration consists of two opposite movements, inspiration and expiration.

1. The **movement of expiration** is performed by (1) the elasticity of the lungs, (2) the weight of the chest walls, (3) the elevation of the diaphragm, (4) the action of muscles—triangularis sterni and muscles of the abdominal wall. It is sometimes stated that the interosseous fibres of the internal intercostal muscles are depressors of the ribs.

2. The **movement of inspiration** results in the enlargement of the thoracic cavity in all its diameters. Its antero-posterior and transverse diameters are increased by the elevation and forward movement of the sternum, and by the elevation and eversion of the ribs, while its vertical diameter is increased by the descent of the diaphragm.

The muscles of **inspiration** are divided into two series—ordinary and accessory.

a. **Ordinary Muscles.**	*b.* **Extraordinary and Accessory Muscles**
Diaphragm	Quadratus lumborum
Intercostals	Pectorales
Scaleni	Serratus magnus
Serrati postici	Sterno-mastoid
Levatores costarum	Latissimus dorsi
	Infra-hyoid muscles
	Extensors of the spine

Of the ordinary muscles the diaphragm is the most important. Its action is twofold—**centrifugal,** elevating the ribs and increasing the transverse and antero-posterior diameters of the thorax, and **centripetal,** drawing downwards the central tendon and increasing the vertical diameter of the thorax. Of the two movements the former is the more important. There has been considerable diversity of opinion regarding the action of the intercostal muscles. It is generally agreed that the external muscles elevate the ribs; it is probable that the whole of each internal muscle acts in the same way, although it has been stated by different observers that the whole internal muscle is a depressor; or that the interosseous part is a depressor, the interchondral portion of the muscle an elevator of the ribs.

FASCIÆ AND MUSCLES OF THE ABDOMINAL WALL.

The space between the margins of the bony thorax and the pelvis is filled up by a series of muscular sheets, covered externally and internally by fasciæ.

FASCIÆ.

The fasciæ of the abdominal wall are—*externally,* the superficial and deep fasciæ; *internally,* the fascia transversalis, which is continuous with the diaphragmatic, lumbar, psoas, iliac, and pelvic fasciæ, and is lined within by the **extra-peritoneal tissue.**

The **superficial fascia** of the abdomen is liable to contain a large quantity of fat. It is separated in the groin into *two layers*: a superficial fatty layer continuous over Poupart's ligament with the fascia of the front of the thigh (p. 356), and a deeper membranous layer attached to the inner half of Poupart's ligament, and more externally to the fascia lata of the thigh below Poupart's ligament. The two layers are separated by the lymphatic glands and the superficial vessels of the groin. Higher up in the abdominal wall the two layers blend together, and passing

downwards over the spermatic cord, they unite to form the fascia and dartos muscle of the scrotum. The attachment of the fascia to the groin prevents the passage into the thigh of fluid extravasated in the abdominal wall.

The **deep fascia** of the abdominal wall resembles similar fasciæ in other situations. It forms an investment for the obliquus externus muscle, and becomes thin and almost imperceptible in relation to the aponeurosis of that muscle.

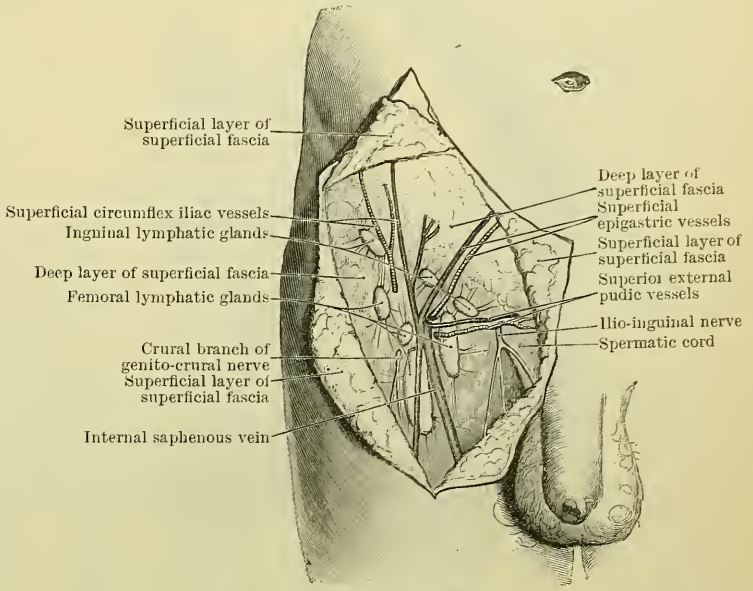


FIG. 337.—THE GROIN. STRUCTURES BETWEEN THE LAYERS OF THE SUPERFICIAL FASCIA.

The **fascial lining** of the abdominal cavity (**fascia transversalis**) consists of a continuous layer of membrane which receives different names in different parts of its extent. It covers the deep surface of the transversalis muscle, and is continuous internally (through the lumbar fascia) with the fasciæ of the quadratus lumborum and the psoas muscles. It is continuous above with the diaphragmatic fascia, and below (the iliac crest and Poupart's ligament intervening) with the fascia iliaca. Along with the last-named fascia it forms the **femoral sheath**. It is pierced by the spermatic cord or round ligament of the uterus at the internal abdominal ring, and its prolongation into the inguinal canal around the cord forms the **infundibuliform fascia**. It is lined internally by the peritoneum, from which it is separated by a layer of **extra-peritoneal tissue**.

The **extra-peritoneal tissue** is usually loaded with fat; it envelops the kidneys, ureters, suprarenal capsules, abdominal aorta and inferior vena cava and their branches, and forms sheaths for the vessels and ducts (ureter, vas deferens, etc.) It is continued upwards into the posterior mediastinum of the thorax through the aortic opening in the diaphragm, and below is in continuity with the extra-peritoneal tissue in the pelvis. It not only completely invests the kidneys and suprarenal capsules, but it also becomes interpolated between the layers of peritoneum upholding and enveloping the intestines. This tissue is absent in relation to the diaphragm, on the under surface of which there is also no fat.

THE MUSCLES OF THE ABDOMINAL WALL.

The muscles of the abdominal wall are in three series—lateral, anterior, and posterior.

The **lateral muscles** of the abdominal wall comprise the obliquus externus, obliquus internus, and transversalis abdominis.

The **obliquus externus abdominis** is a broad thin sheet of muscle, with an **origin** from the outer surfaces of the lower eight ribs, by slips which interdigitate with the serratus magnus and latissimus dorsi muscles. The muscular fibres radiate downwards and forwards, the lowest fibres passing vertically downwards. The lower and posterior part of the muscle is **inserted** directly by fleshly fibres into the outer lip of the iliac crest in its anterior half or two-thirds (Fig.

290, p. 373). The rest of the muscle is inserted into an extensive triangular aponeurosis covering the anterior abdominal wall. This aponeurosis is broader below than above; it is united with part of the aponeurosis of the obliquus internus in the upper three-fourths of its extent, to form the anterior layer of the **sheath of the rectus muscle**. It thus gains an attachment, above to the ensiform cartilage, below to the symphysis pubis, and by its intermediate fibres to the **linea alba**, a broad interlacing band of fibres about half an inch in width which occupies the middle line of the anterior abdominal wall in its whole extent, and forms the greater part of the ultimate insertion of all the lateral abdominal muscles.

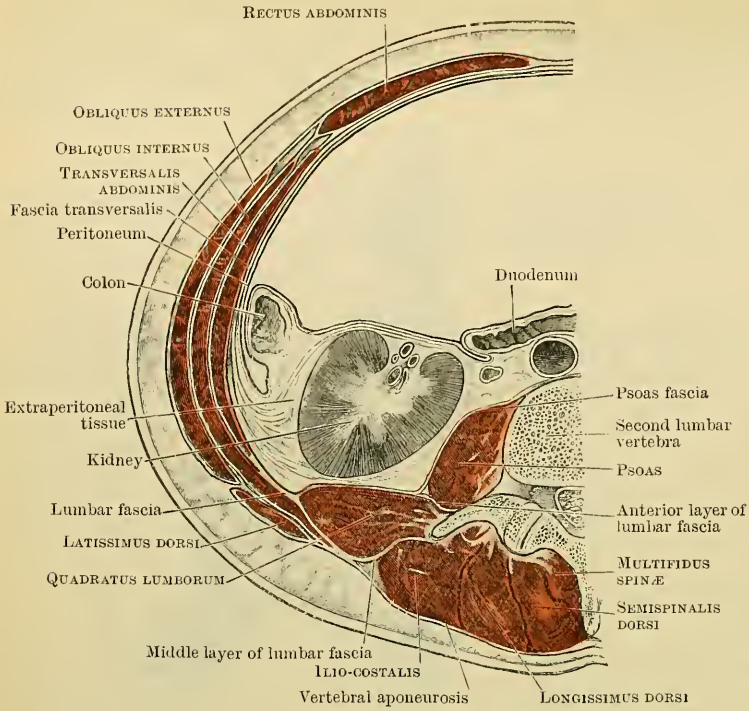


Fig. 338.—Transverse Section through the Abdomen, opposite the Second Lumbar Vertebra.

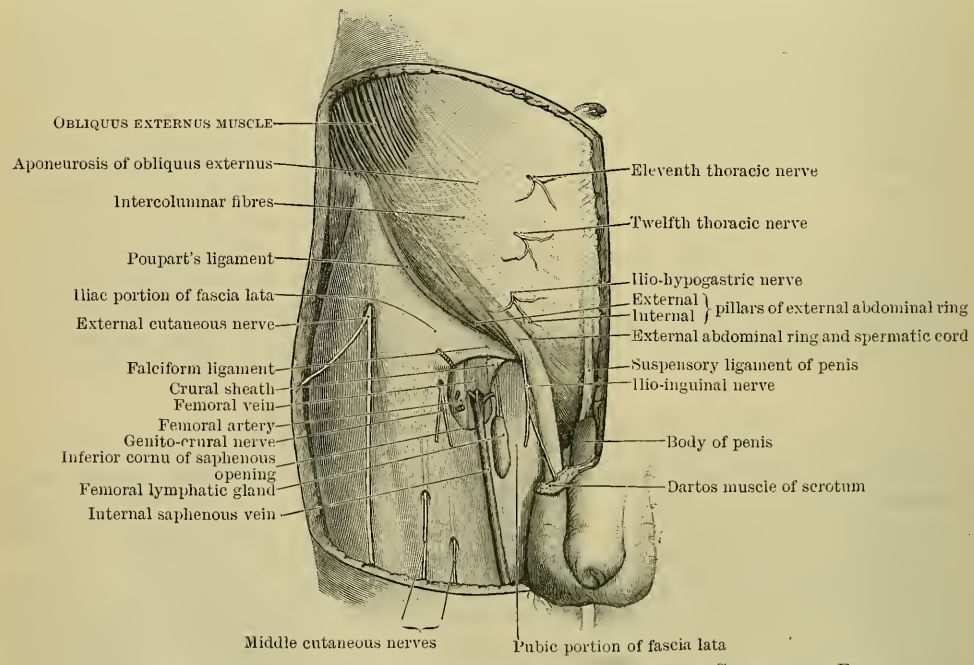


Fig. 339.—The Groin. The Structures seen on removal of the Superficial Fascia.

The upper part of the aponeurosis covers the insertion of the rectus abdominis

muscle on the chest wall, and gives origin to fibres of the pectoralis major. Below, in the groin, it gives rise to Poupart's ligament, Gimbernat's ligament, the external abdominal ring with its two pillars, the intercolumnar fascia and fibres, and the triangular fascia.

Poupart's ligament is a fascial band which extends from the anterior superior

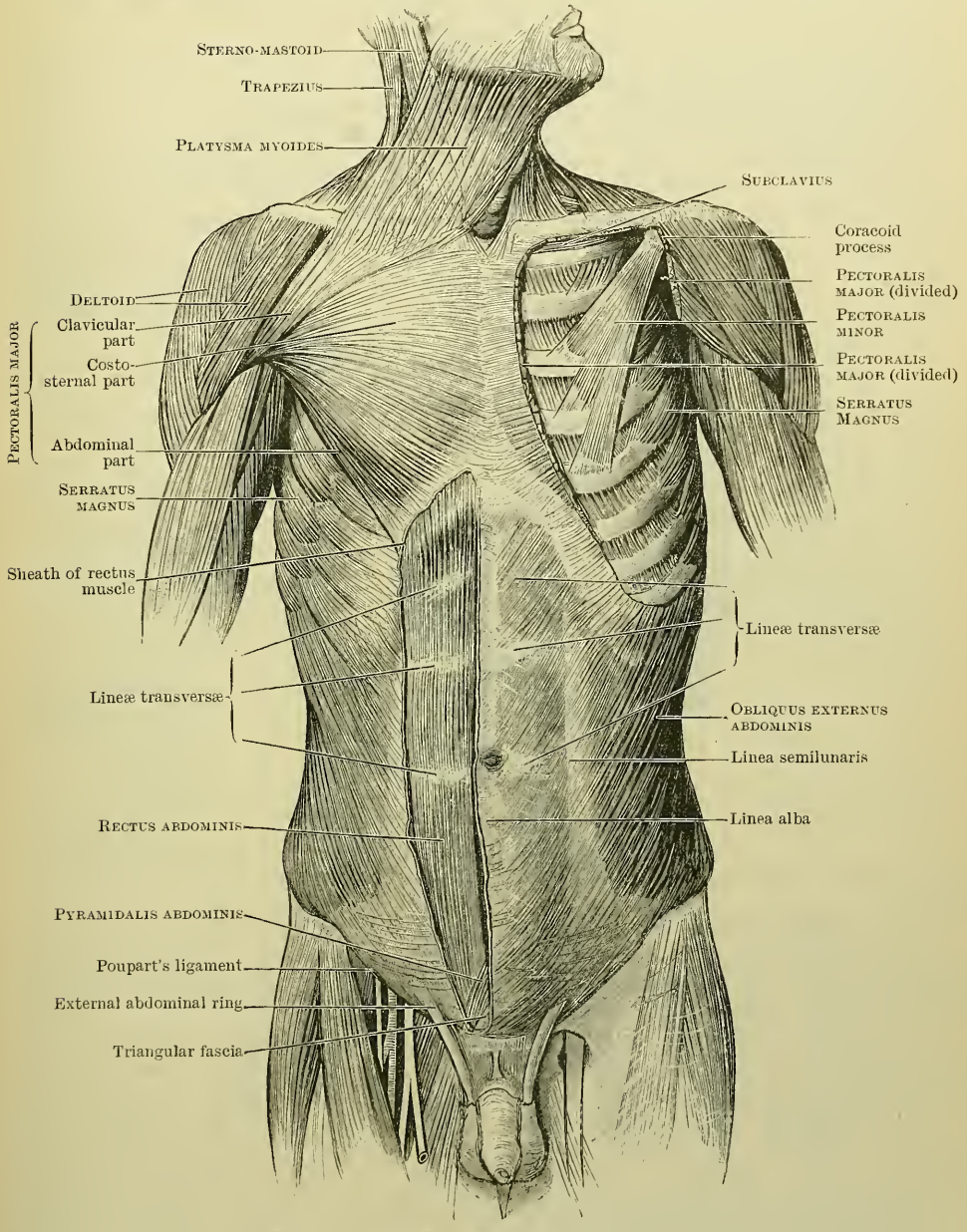


Fig. 340.—Anterior Muscles of the Trunk.

iliac spine to the spine of the pubis, arching over the iliacus, psoas, and pectineus muscles. It represents the lower limit of the aponeurosis of the obliquus externus abdominis, and gives attachment below to the fascia lata of the thigh. Its outer part affords partial origin to the deeper lateral muscles of the abdominal wall, and receives the attachment of the fascia transversalis and fascia iliaca; the inner part forms the gutter-like floor of the inguinal canal. At its inner end a triangular band of fibres is reflected horizontally backwards to the ilio-pectineal line, forming

Gimbernat's ligament, the outer edge of which limits internally the **crural ring**. The femoral vessels enclosed in the femoral sheath enter the thigh beneath Poupart's ligament, in front of the psoas muscle, and the term *superficial crural arch* is given to the part of the ligament which covers the vessels.

The **external abdominal ring**, the place of exit of an inguinal hernia, is a split in the aponeurosis of the obliquus externus, just above the spine of the pubis. It transmits the spermatic cord, or round ligament of the uterus, covered by the cremaster muscle or cremasteric fascia. The opening is of considerable extent, and its edges are drawn together by a thin fascia, strengthened superficially by a number of arched and horizontal fibres, called the **intercolumnar fibres**, which arise from Poupart's ligament and sweep inwards across the cleft in the aponeurosis.

The margins of the ring constitute its pillars. The **external pillar** is narrow, and is formed from that part of the aponeurosis which joins the pubic spine, and is continuous with the inner end of Poupart's ligament. The **internal pillar** is the part of the aponeurosis internal to the ring which is attached to the crest and symphysis of the pubis. It is flat and broad.

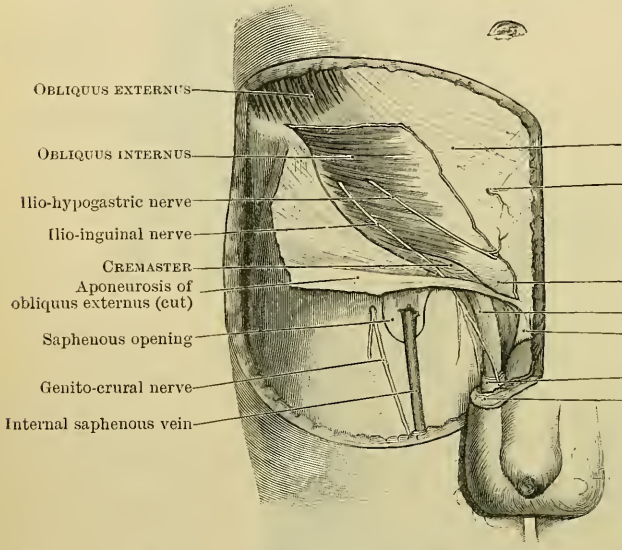


Fig. 341.—The Groin. The Structures seen on removal of part of the Obliquus Externus.

The intercolumnar fibres and the pillars of the external abdominal ring are continuous with a thin tubular sheath, the **intercolumnar** or **external spermatic fascia**, which is attached to the margins of the "ring," and forms an envelope for the spermatic cord or round ligament in their further passage beyond the abdominal wall.

The **triangular fascia**, lastly, is a triangular band of fibres placed behind the internal pillar of the external abdominal ring. It consists of fibres from the *opposite* external oblique aponeurosis, which, having traversed the linea alba, gain an insertion into the crest and spine of the pubis.

The obliquus externus muscle is superficial in almost its whole extent. It is overlapped posteriorly by the latissimus dorsi muscle, but may be separated from it just above the iliac crest by an angular interval (triangle of Petit).

The **obliquus internus abdominis**, a broad thin sheet lying between the obliquus externus and the transversalis, **arises** from (1) the lumbar fascia, (2) the anterior half of the iliac crest, and (3) the outer half of Poupart's ligament. Directed for the most part upwards and forwards, its highest fibres are **inserted** directly into the last three ribs. The rest of the fibres form an extensive aponeurosis, broader above than below, which splits along the **linea semilunaris**, to form, along with the aponeuroses of the obliquus externus and transversalis muscles, the **sheath of the rectus abdominis**, and is thereafter inserted into the seventh, eighth, and ninth costal cartilages, and into the linea alba from the ensiform cartilage to the symphysis pubis. The fibres arising from Poupart's ligament join with those of the transversalis muscle having a similar origin to form the **conjoint tendon**, which passes altogether in front of the rectus muscle, to be attached to the pubic crest and spine and to the ilio-pectineal line.

The obliquus internus is limited above by the costal arch. Its lower fibres, arching over the spermatic cord, assist in forming, externally, the anterior wall of the inguinal canal; internally, by means of the conjoint tendon, it helps to form the posterior wall of the canal.

Its lowest fibres are continued into the **cremaster muscle**, which is prolonged along the spermatic cord through the inguinal canal.

The **cremaster muscle** may be said to have an **origin** from the lower border of the obliquus internus, and from the centre of Poupart's ligament. It forms a thin sheet, enveloping the testicle and spermatic cord; its fibres are arranged in loops which arch over the cord, and are **inserted** into the fascia, and to a less extent (uppermost fibres) into the pubic spine. The muscle is more largely represented by fascia in the female, and constitutes the **cremasteric fascia.**

The **transversalis muscle** arises (1) from the under surface of the costal cartilages of the lower six ribs, inter-digitating with the origins of the diaphragm; (2) from the lumbar fascia; (3) from the anterior half of the inner lip of the iliac crest; and (4) from the outer third of Poupart's ligament. The muscular fibres

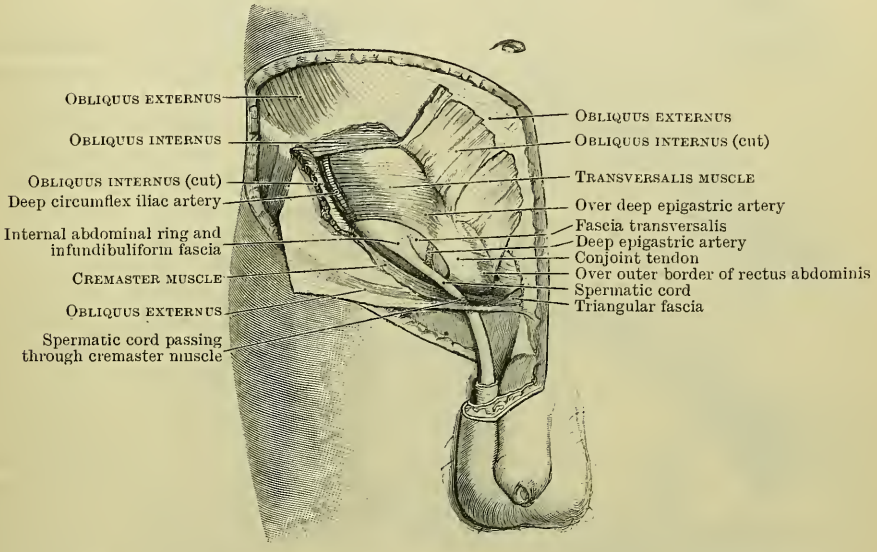


Fig. 342.—The Groin. The Structures seen on reflexion of part of the Obliquus Internus.

are directed for the most part horizontally forwards, and end in an aponeurosis which has a twofold **insertion.** (1) After forming (along with the aponeurosis of the obliquus internus) the posterior layer of the sheath of the rectus, the aponeurosis is attached to the ensiform cartilage and linea alba. (2) The lower fibres of the muscle arising from Poupart's ligament are joined by the lower part of the obliquus internus to form the larger part of the **conjoint tendon**, which passes in front of the lower part of the rectus muscle, to be inserted into the crest and spine of the pubis and the ilio-pectineal line.

The transversalis muscle is separated by the lower intercostal nerves from the obliquus internus muscle, and is lined on its deep surface by the transversalis fascia. Its lower border forms a concave edge, separated from Poupart's ligament by a lunular interval in which the transversalis fascia appears, and through which the spermatic cord emerges at the internal abdominal ring, under cover of the obliquus internus muscle and the aponeurosis of the obliquus externus.

The **anterior muscles** of the abdominal wall include the pyramidalis and rectus abdominis, enveloped by the sheath of the rectus on either side of the linea alba.

The **pyramidalis abdominis** is a small triangular muscle **arising** from the pubic crest in front of the rectus muscle (Fig. 282, p. 366). It is directed obliquely

upwards, to be **inserted** for a variable distance into the linea alba. The muscle is often absent.

The **rectus abdominis muscle** is broad and strap-like, and **arises**, by an inner and an outer head, from the symphysis and crest of the pubis (Fig. 282, p. 366). Expanding as it passes upwards, the muscle is **inserted** from within outwards into the front of the ensiform cartilage (Fig. 246, p. 322), and into the front of the seventh, sixth, and fifth costal cartilages. On its anterior surface, but not extending through the entire substance of the muscle, are three or more transverse tendinous intersections (**lineæ transversæ**), adherent to the sheath of the muscle; the lowest opposite the umbilicus, and the highest about the level of the ensiform cartilage. Enclosed in its sheath, and covered anteriorly by the pyramidalis muscle, the rectus conceals the superior and deep epigastric vessels, the terminal branches of the lower thoracic nerves (which pierce the muscle to reach the anterior abdominal wall), the fold of Douglas, and the fascia transversalis. The inner border of the muscle lies alongside the linea alba; its outer border is convex, and corresponds to the **linea semilunaris**.

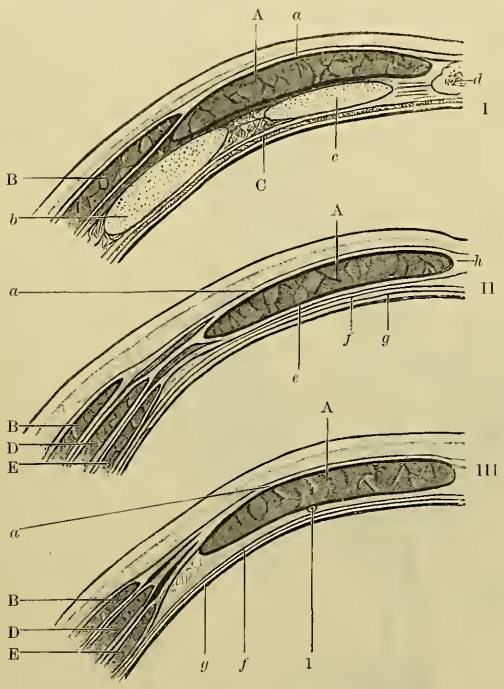


FIG. 343.—THE SHEATH OF THE RECTUS ABDOMINIS MUSCLE.

(I.) In the thoracic wall; (II.) In the upper three-quarters of the abdominal wall; (III.) In the lower fourth of the abdominal wall.

A, RECTUS MUSCLE; B, OBLIQUUS EXTERNUS; C, DIAPHRAGM; D, OBLIQUUS INTERNUS; E, TRANSVERSALIS ABDOMINIS. *a*, Anterior layer of rectus sheath; *b*, Fifth costal cartilage; *c*, Sixth costal cartilage; *d*, Xiphoid cartilage; *e*, Posterior layer of rectus sheath; *f*, Transversalis fascia; *g*, Peritoneum; *h*, Linea alba. 1, Deep epigastric artery.

The **sheath of the rectus muscle** is derived from the aponeuroses of the lateral muscles of the abdominal wall, which, after enclosing the muscle, give rise in the middle line to the linea alba. At the linea semilunaris, at the outer border of the rectus muscle, the aponeurosis of the obliquus internus splits into anterior and posterior layers. The anterior layer, joined by the aponeurosis of the obliquus externus, passes in front of the rectus, and constitutes the anterior lamina of the sheath. The posterior layer, joined by the aponeurosis of the transversalis muscle, passes behind the rectus, and constitutes the posterior lamina of its sheath. This arrangement obtains in the upper three-fourths of the abdominal wall. Below the level of the iliac crest the sheath of the muscle is deficient posteriorly, and a crescentic border, the **fold of Douglas**, marks the lower limit of the posterior lamina. In consequence, the rectus in the lower fourth of the abdominal wall rests upon the fascia transversalis directly. Close examination, however, usually reveals a thin layer behind the muscle in continuity with the fold of Douglas, and merging below with the fascia transversalis. In this region the rectus is covered anteriorly by the conjoint tendon of the obliquus internus and transversalis, and by the aponeurosis of the obliquus externus, which is gradually becoming separate from the subjacent aponeurosis. The upper part of the rectus, lying on the chest wall, is only covered anteriorly by a single layer of aponeurosis derived from the obliquus externus, which in this situation is giving origin to the pectoralis major muscle.

Inguinal Canal.—The spermatic cord in the male, and the round ligament in the female, in their passage through the lower part of the abdominal wall, pass through the inguinal canal, which is bounded by these abdominal muscles. The canal begins at the *internal abdominal ring*, placed half an inch above Poupart's

ligament, and midway between the anterior superior iliac spine and the symphysis pubis. It ends at the *external abdominal ring*, placed above the spine and crest of the pubis. The *front wall* of the canal is formed by the aponeurosis of the obliquus externus, and in its outer part by the muscular fibres of the obliquus internus; the *back wall* of the canal is formed by the fascia transversalis, and in its inner part by the conjoint tendon; while the *floor* of the canal is formed by

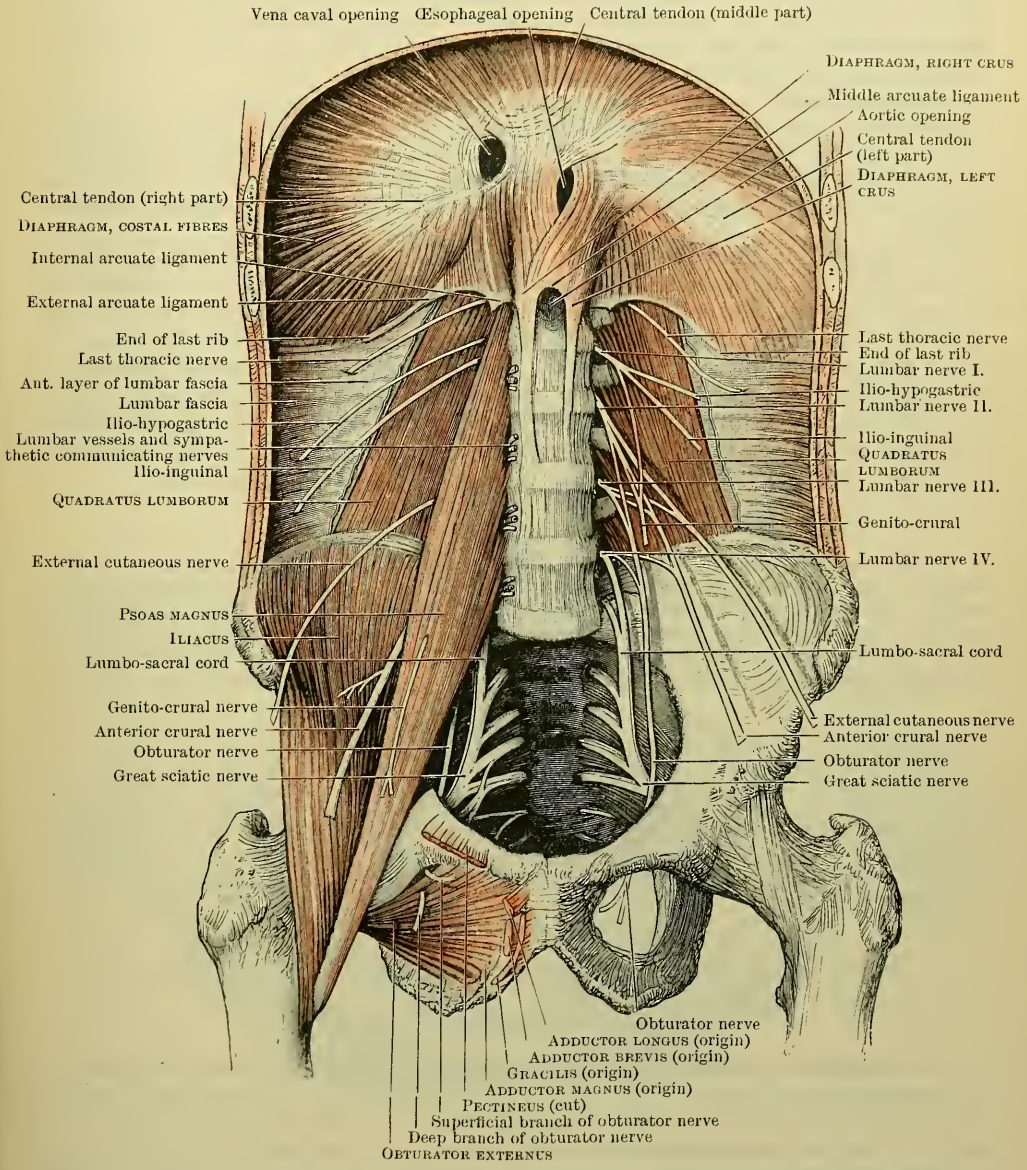


Fig. 344.—View of the Posterior Abdominal Wall, to show the Muscles and the Nerves of the Lumbo-Sacral Plexus.

Poupart's ligament, and in its inner part by Gimbernat's ligament. The spermatic cord, piercing the transversalis fascia, enters the inguinal canal at the internal abdominal ring, and is there invested by its *first envelope*, the **infundibuliform** or **internal spermatic fascia**, a sheath of fascia derived from the margin of the ring and continuous with the fascia transversalis. It then passes obliquely inwards, downwards, and forwards, and escapes below the lower border of the obliquus internus muscle, from which it carries off a *second investment*, partly fascial, partly muscular

—the **cremaster muscle** or **cremasteric fascia**. Continuing its course in front of the conjoint tendon, it emerges through the external abdominal ring, from the edges of which the **intercolumnar fascia** is derived, the *third* or *external investment* for the cord.

Hesselbach's triangle, bounded below by the line of Poupart's ligament, internally by the rectus abdominis muscle, and externally by the deep epigastric artery on the mesial side of the internal abdominal ring, is the site of one form of inguinal hernia. The spermatic cord passes over the base of the triangle, covered over by the aponeurosis of the obliquus externus. Behind the cord, and forming the floor of the triangle, are the fascia transversalis and the conjoint tendon of the obliquus internus and transversalis muscles.

Inguinal Hernia.—For an account of the anatomical relations of the inguinal canal to the various forms of inguinal hernia, see the section on "Applied Anatomy."

The **posterior muscles of the abdominal wall and false pelvis** include the psoas (magnus and parvus) and iliacus, described already (p. 363), and the quadratus lumborum.

The **quadratus lumborum** lies on the posterior wall of the abdomen external to the psoas, and extends between the iliac crest and the last rib. It **arises** from the posterior part of the iliac crest, from the ilio-lumbar ligament, and from the transverse processes of the lower lumbar vertebræ. It is **inserted** above into the inner part of the lower border of the last rib and the transverse processes of the upper lumbar vertebræ. It is enclosed between the anterior and middle layers of the lumbar aponeurosis (p. 391), and is placed behind the colon, kidney, and psoas muscle, in front of the multifidus spinæ and the lumbar transverse processes. Its outer border is directed obliquely upwards and inwards.

Nerve-Supply.

The nerve-supply of all the foregoing muscles except the psoas, cremaster, quadratus lumborum, and iliacus, is derived from the anterior primary divisions of the **lower six thoracic nerves**. The pyramidalis muscle is innervated by the **last thoracic nerve**. The cremaster muscle receives its supply from the **genito-crural nerve**, whilst the quadratus lumborum is innervated by the first three or four **lumbar nerves**. The psoas and iliacus muscles are supplied, directly or through the **anterior crural nerve**, from the second, third, and fourth lumbar nerves.

Actions.

Many of the actions of the above muscles have already been given in previous sections. (1) Their chief action is to retract the abdominal walls, and, by compressing the contents of the abdomen, they are powerful agents in vomiting, defæcation, micturition, parturition, and laboured expiration. (2) They are also flexors of the spine and pelvis—the muscles of both sides acting together; the spine and pelvis are laterally flexed, when one set of muscles acts alone. (3) The quadratus lumborum is a muscle of inspiration, an extensor of the spine, and a lateral flexor of the spine and pelvis.

FASCIÆ AND MUSCLES OF THE PERINEUM AND PELVIS.

FASCIÆ OF THE PERINEUM.

The **superficial fascia** of the perineum possesses certain special features. It is continuous with the superficial fascia of the abdominal wall, thigh, and buttock, and is prolonged on to the penis and scrotum. In relation to the penis, it is devoid of fat and consists only of areolar tissue. In relation to the scrotum, it is intermingled with involuntary muscular fibres, and constitutes the **dartos muscle**, which assists in suspending the testicles and corrugating the skin of the scrotum. This fascia also forms the **septum of the scrotum**, which, extending upwards, incompletely separates the two testicles and their coverings. In the female the superficial fascia takes a large share in the formation of the mons veneris and labia majora, in which a considerable quantity of fat occurs.

The fascia over the posterior part of the perineum fills up the ischio-rectal fossæ, in the form of two pads of adipose tissue, on either side of the rectum and anus. Over the tuberosities of the ischium the fat is largely replaced by bands of fibrous tissue closely adherent to the subjacent deep fascia.

The fascia in the anterior part of the perineum closely resembles the same fascia in the groin. It is divisible into a superficial fatty and a deeper membranous layer; the former continuous with the same layer in the thigh, and with the fat of the ischio-rectal fossa posteriorly. The deeper membranous layer is attached laterally to the pubic arch, posteriorly to the base of the triangular ligament, and in the middle line to the root of the penis (bulb and corpus spongiosum) by a median raphe continuous farther forwards with the septum of the scrotum mentioned above. Anteriorly the fascia is continued over the spermatic cords to the anterior abdominal wall. The importance of this fascia lies in relation to the extravasation of urine from a rupture of the urethra. By the fascial attachments the fluid is prevented from passing backwards into the ischio-rectal fossa, or laterally into the thigh. It is directed forwards into relation with the scrotum and penis, and along the spermatic cord to the anterior abdominal wall. The septum of the scrotum being incomplete, fluid extravasated on one side can pass across the middle line to the opposite half of the perineum and scrotum.

The **deep fascia** of the perineum only exists in the form of the delicate aponeuroses of the muscles.

THE MUSCLES OF THE PERINEUM.

The perineal muscles are naturally separated into a superficial and a deep set by the triangular ligament. Superficially are the sphincter ani externus, transversus

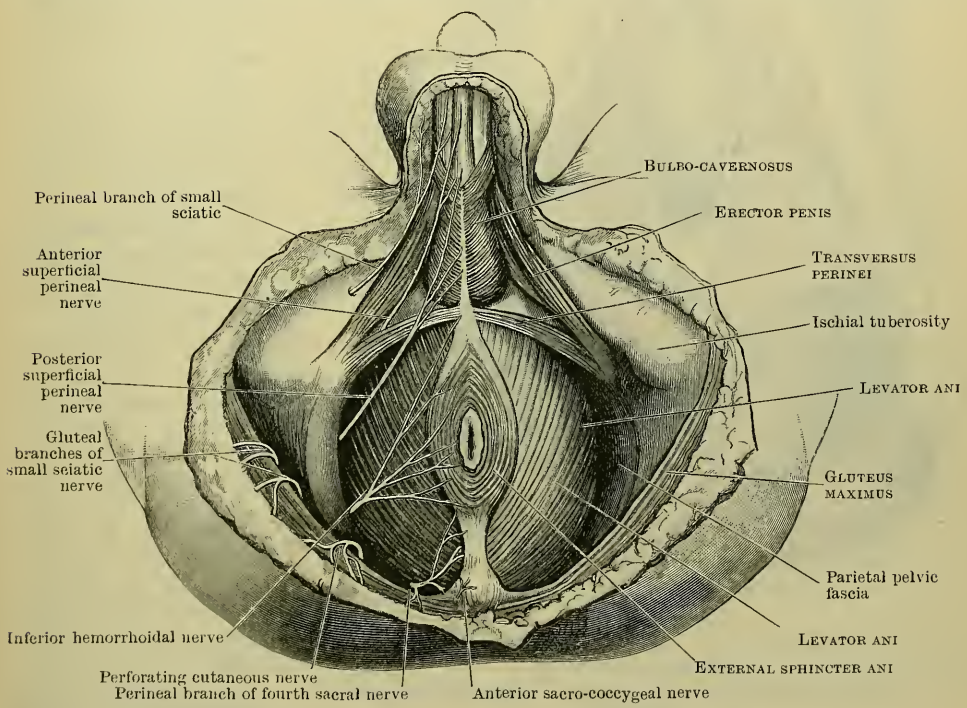


Fig. 345.—The Muscles and Nerves of the Male Perineum.

perinei superficialis, bulbo-cavernosus, and ischio-cavernosus; beneath the triangular ligament is the compressor urethræ.

Sphincter ani Externus.—This muscle is fusiform in outline, flattened, and obliquely placed around the anus and anal canal. It can be separated into three layers,—subcutaneous, superficial, and deep. (1) The most **superficial lamina** consists of subcutaneous fibres decussating behind and in front of the anus, but without bony attachments. (2) The **sphincter ani superficialis** constitutes the main portion of the muscle. It is attached posteriorly to the coccyx, and in front of the anus reaches the central point of the perineum. (3) The **deep fibres**

of the muscle form for the most part a complete sphincter for the anal canal. They are continuous with the fibres of the levator ani; they encircle the anal canal, and blend anteriorly with the central point of the perineum and the transversus perinei.

The muscle surrounds the anus, covered only by the skin, superficial fascia, and the **corrugator cutis ani** (a series of non-striated muscular fibres radiating from the anal opening). It rests on the edge of the levator ani, and forms the median boundary of the ischio-rectal fossa.

The **transversus perinei superficialis** is not always present. It consists of a more or less feeble bundle of fibres, **arising** from the ascending ramus of the ischium and the fascia over it, and from the base of the triangular ligament. It is directed inwards and forwards to be **inserted** into the central point of the perineum. It conceals the base of the triangular ligament, and has a variable relation to the superficial perineal vessels and nerves.

The **bulbo-cavernosus** (ejaculator urinæ), *in the male*, surrounds the bulb, corpus spongiosum, and root of the penis. It is sometimes separated into two parts—*posterior* (compressor bulbi), and *anterior* (compressor radicis penis). It **arises** from the central point of the perineum, and from a median raphe on the under surface of the bulb and corpus spongiosum. The muscular fibres are directed outwards and forwards, and have a triple **insertion**: from behind forwards, (1) into the under surface of the triangular ligament; (2) into the membrane covering the corpus spongiosum; and (3), after encircling the corpora cavernosa, into the fascia covering the dorsum of the penis.

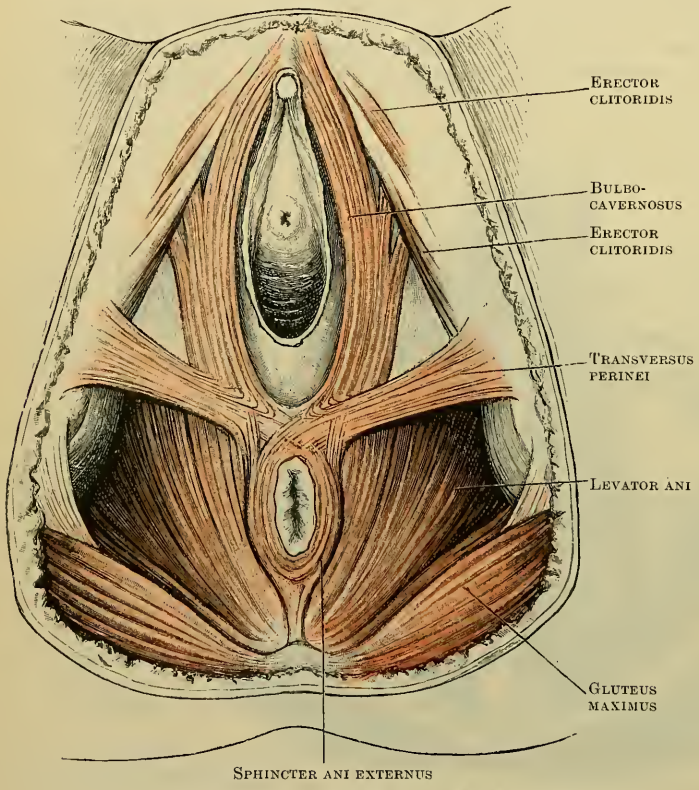


Fig. 346.—The Muscles of the Female Perineum (after Peter Thompson).

The **ischio-bulbosus**, not always present, **arises** from the ischium, and passes obliquely inwards and forwards over the bulbo-cavernosus, to be **inserted** into the raphe superficial to that muscle. It belongs to the same stratum as the transversus perinei and erector penis.

The **compressor hemispherium bulbi** is frequently absent. It consists of a thin cap-like layer of muscular fibres surrounding the extremity of the bulb under cover of the bulbo-cavernosus.

The **bulbo-cavernosus** (sphincter vaginæ), *in the female*, is separated into lateral halves by the vaginal and urethral openings. It forms two thin lateral layers covering the vaginal bulbs, and **arises** behind the vaginal orifice from the central point of the perineum. Anteriorly it is **inserted** into the root of the clitoris, some of its fibres embracing the corpora cavernosa so as to reach the dorsum of the clitoris.

The **ischio-cavernosus** (erector penis), *in the male*, covers the crus penis. It

arises from the ischial tuberosity and the great sacro-sciatic ligament, and passing forwards, is **inserted** by a fascial attachment into the under surface of the crus penis, and into the outer side and dorsal aspect of the corpus cavernosum.

The **ischio-cavernosus** (erector clitoridis), *in the female*, has a similar disposition, but is of much smaller size than in the male.

The **pubo-cavernosus** is an occasional slip **arising** from the pubic ramus, and **inserted** into the dorsum of the penis. It corresponds to the levator penis of lower animals.

The **compressor urethræ** (constrictor urethræ) constitutes the deeper muscular stratum of the perineum. It is placed on the pelvic aspect of the triangular ligament. It **arises** from the lower part of the pubic ramus, and is directed inwards, its fibres radiating so as to enclose the membranous urethra. It is **inserted** into a median raphe, partly in front of the urethra, but for the most part behind it. The fibres most intimately related to the urethra form a tubular sheath for the canal, and have no bony attachments.

The most anterior and most posterior fibres of the compressor urethræ exist sometimes as separate muscles.

The **transversus perinei profundus** consists of a bundle of fibres on either side, **arising** from the ascending ramus of the ischium just below the compressor urethræ. It is **inserted** into a median raphe continuous with that of the compressor urethræ. The muscle, in fact, constitutes a separate bundle below and behind the compressor urethræ.

The **ischio-pubicus** is a term applied to a feeble bundle of fibres which, when

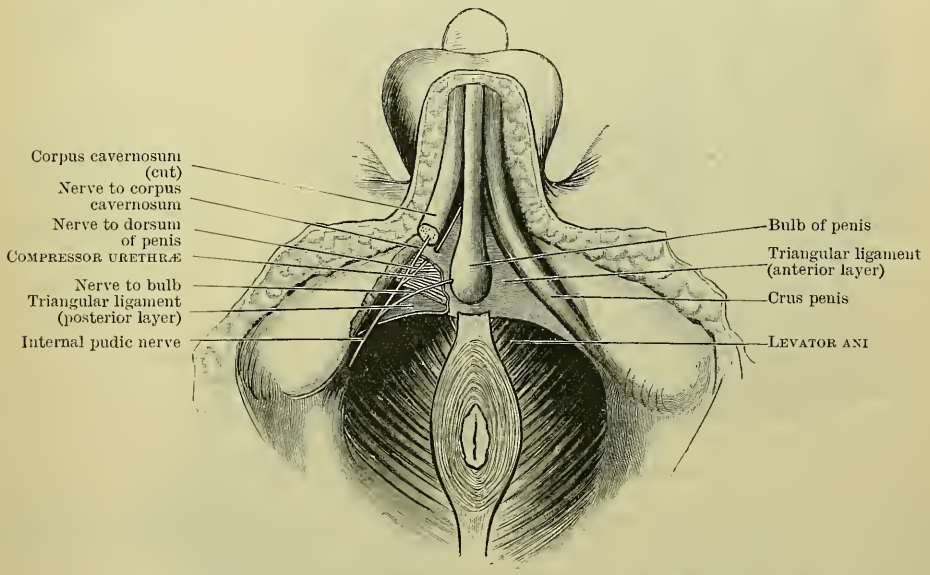


FIG. 347.—THE TRIANGULAR LIGAMENT OF THE PERINEUM, AND THE TERMINATION OF THE PUDIC NERVE.

present, lies above and in front of the compressor urethræ. It **arises** from the pubic ramus, and is **inserted** into a median raphe in front of the membranous urethra. This muscle is homologous with the **compressor venæ dorsalis penis** of lower animals.

The **compressor urethræ** *in the female* is smaller than in the male. Its insertion is modified by the relations of the urethra to the vagina. The anterior fibres are continuous with those of the opposite side in front of the urethra; the intermediate fibres pass between the urethra and vagina, and the posterior fibres are attached, along with the **transversus perinei profundus** (transversus vaginæ), into the side of the vagina.

NERVE-SUPPLY.

The **pudic nerve** (S. 2. 3. 4.) supplies all the muscles in this group; the external sphincter through the inferior hæmorrhoidal, and the others through the perineal branch of the nerve. The external sphincter is also supplied by the perineal branch of the **fourth sacral nerve.**

ACTIONS.

The **external sphincter** closes the anal canal. The **transversus perinei superficialis** draws back and fixes the central point of the perineum, assisted by the external sphincter. The **bulbo-cavernosus** of the male constricts the bulb and corpus spongiosum, and so expresses the last drops of urine or semen. In the female it acts as a feeble sphincter of the vagina. The **ischio-cavernosus** and **bulbo-cavernosus** help in erection of the penis or clitoris. The **compressor urethræ** constricts the membranous urethra, and in the female helps to flatten and fix the wall of the vagina. It also assists in causing erection of the penis or clitoris by compression of the veins in relation to it.

FASCIA OF THE PELVIS.

The pelvic basin, placed obliquely, deeper and more hollowed behind than in front, and imperfect in its bony boundaries, is to a large extent completed by ligaments. The sacro-sciatic ligaments behind, the obturator membrane laterally, and the triangular ligament in front assist in filling up its osseous deficiencies. It is almost entirely clothed internally by muscles: by the pyriformis on each side behind, the obturator internus at the side, and the compressor urethræ in contact

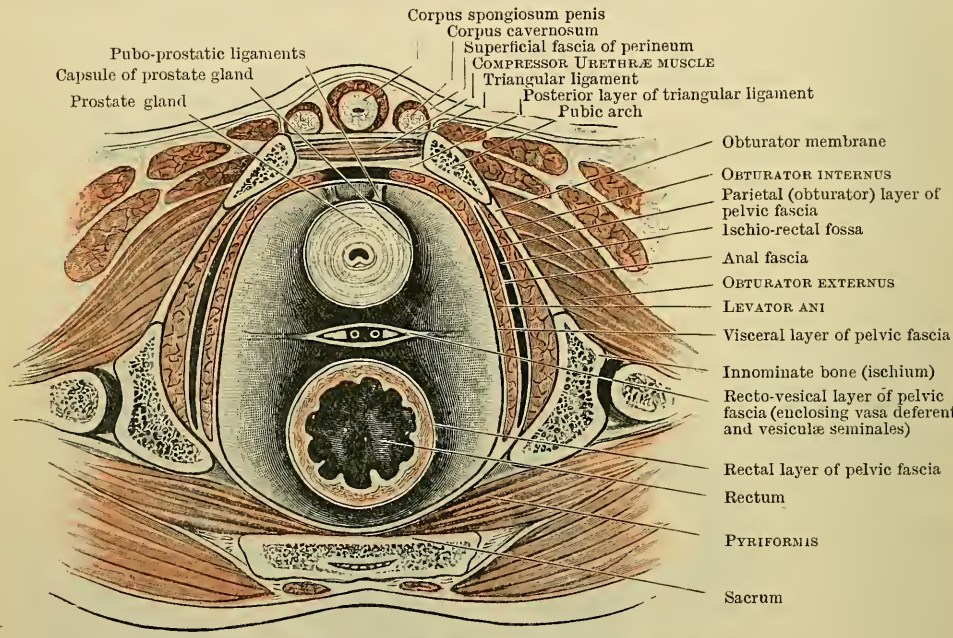


Fig. 348.—Dissection of the Pelvic Fascia from Above (diagrammatic).

with the triangular ligament in front. Indeed, the bones of the pelvis only project into the cavity in three places; the spines of the ischium project into the cavity on each side, and the pubis appears in its anterior wall.

The pelvic fascia forms a cylindrical membrane lining the wall of the pelvis, as an aponeurosis for its muscles. It is attached above and below to the inlet and outlet of the pelvis; above to the promontory of the sacrum, ilio-pectineal line, and back of the pubis; below to the coccyx, great sacro-sciatic ligament, tuber ischii, and the base of the triangular ligament. This cylindrical membrane is the **parietal pelvic fascia**; it forms the **pyriformis fascia** behind, the **obturator fascia** at the side of the pelvis, and the so-called **posterior layer** of the **triangular ligament** in front. As this fascia lines the pelvic wall it obtains attachments to the projecting bones, to the back of the pubis anteriorly, and to the spine of the ischium on each side. It is deficient in relation to the obturator groove, through which the obturator artery and nerve pass to reach the thigh.

The **white line**, a thickened band of the fascia, extends between the back of the pubis and the spine of the ischium, and roughly indicates the line of separation of the pelvic cavity from the ischio-rectal fossa. The white line serves two purposes; it gives origin to fibres of the levator ani muscle, and also to a secondary

sheet of fascia, known as the **visceral pelvic fascia**, which arches downwards and inwards across the floor of the pelvis to be connected with the pelvic viscera. This membrane is thin and unimportant behind, as it passes forwards from the lower sacral vertebræ to the rectum. It is thicker at the sides and front of the pelvis, where it forms a stout membrane concave upwards, continuous mesially with the fibrous coats of the rectum and bladder, and enveloping the prostate gland and vesiculæ seminales. At the front of the pelvis this layer extends from the back of the pubis, to which it is directly attached, to the neck of the bladder and prostate gland, and gives rise to two lateral folds—the **pubo-prostatic ligaments**, which enclose between them a hollow on the pelvic aspect of the fascia, known as the **cavum Retzii**. The lateral portion of the visceral pelvic fascia constitutes the **recto-vesical layer**, divisible into three parts—*vesical*, *rectal*, and between these the *recto-vesical layer*, a partition insinuated between the rectum and bladder, and enclosing the vesiculæ seminales and vasa deferentia. This visceral pelvic fascia thus forms a support for the pelvic viscera, and at the same time acts as a partition between the pelvic cavity and the perineum. It is separated from the pelvic cavity by the peritoneum and the extra-peritoneal tissue, and is in contact with the levator ani muscle on its perineal surface. The internal iliac vessels and their branches lie on the pelvic aspect of the fascia, and the parietal vessels pierce it, and are ensheathed by it as they leave the pelvis. On the other hand the spinal nerves forming the sacral plexus lie outside the fascia with one exception. The obturator nerve, after piercing the inner border of the psoas muscle and the psoas fascia, leaves the pelvis through a special hole in the pelvic wall, after traversing the extra-peritoneal tissue.

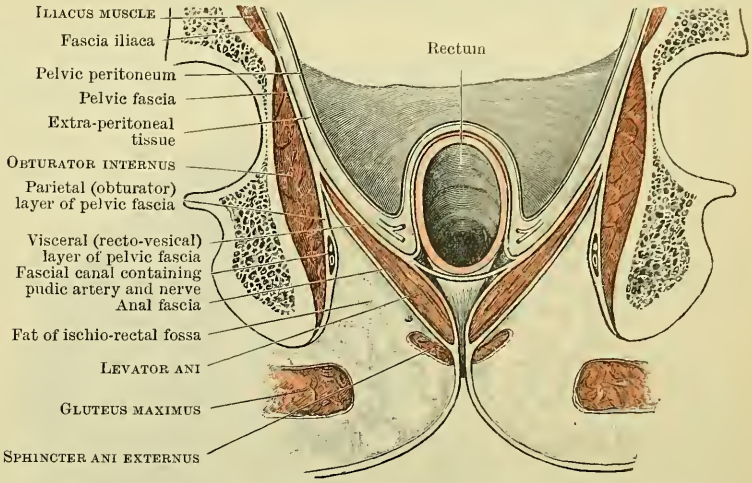


Fig. 349.—Oblique Section across the Pelvis, to show the Disposition of the Pelvic Fascia and the Boundaries of the Ischio-Rectal Fossa.

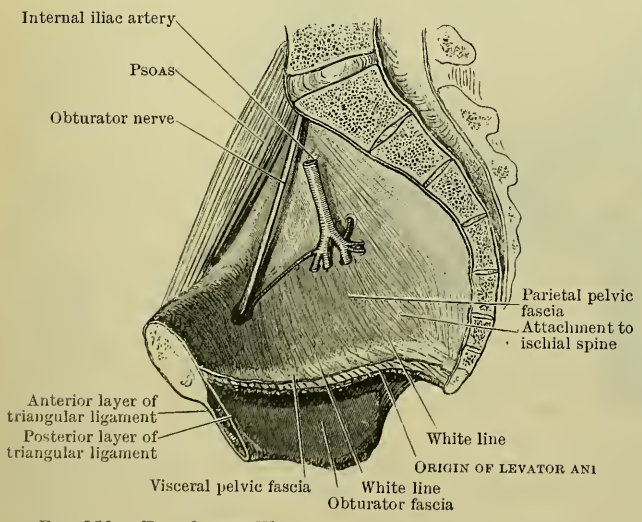


Fig. 350.—The Outer Wall of the Pelvis (Pelvic Fascia).

The *pelvic fascia in the female* only differs in slight detail from that of the male. It encloses the neck of the bladder and vagina instead of the prostate gland, and invests the lower part of the neck of the uterus instead of the vesiculæ seminales.

MUSCLES OF THE PELVIS.

The pelvic diaphragm consists of several more or less rudimentary muscular slips, constituting the levator ani and ischio-coccygeus muscles, which serve to uphold the pelvic floor, and are related to the rectum and the prostate gland or vagina.

The **levator ani** arises from (1) the back of the body of the pubis, (2) the parietal pelvic fascia above or along the *white line*, and (3) the spine of the ischium.

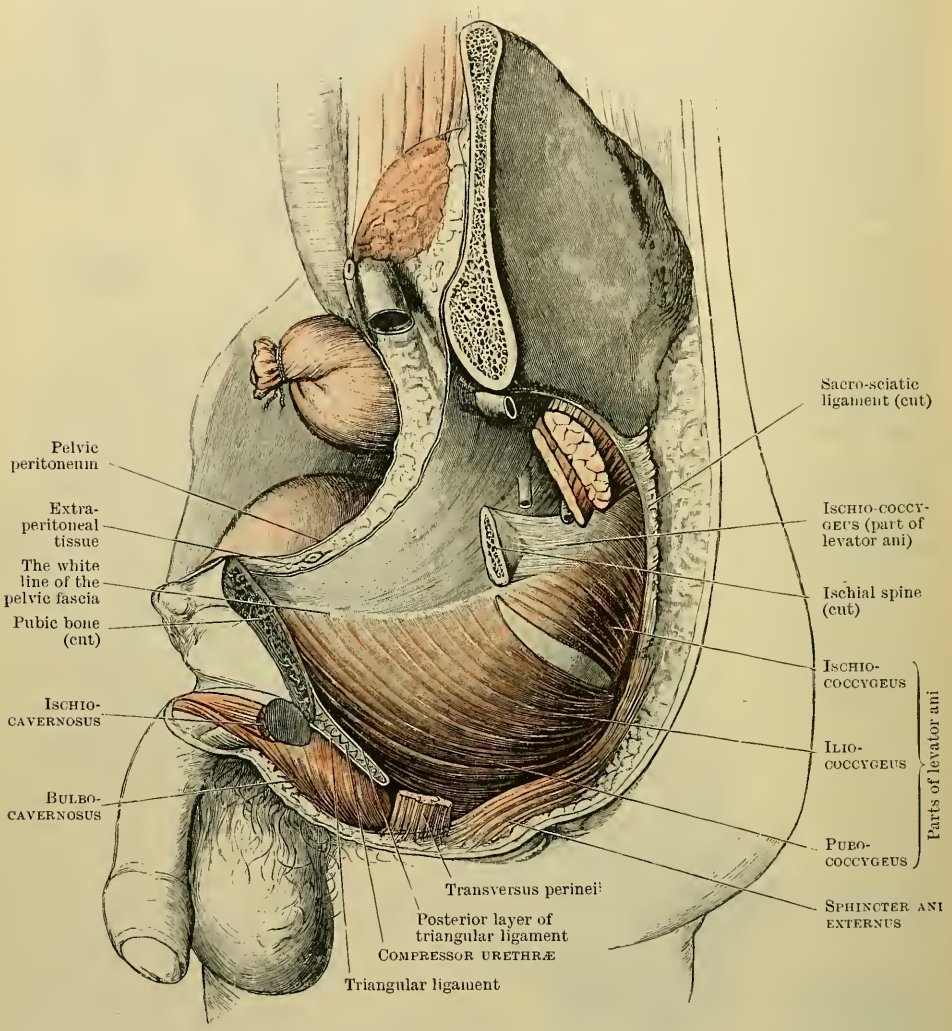


Fig. 351.—The Fascial and Muscular Wall of the Pelvis after Removal of Part of the Left Innominate Bone.

Its fibres are directed downwards and backwards, to be **inserted** into (1) the central point of the perineum, (2) the external sphincter around the anus and the ano-coccygeal raphe behind the anus, and (3) into the sides of the lower sacral and the coccygeal vertebræ.

The concave upper surface of the muscle is covered in part by the visceral pelvic fascia; in part it is in contact with the rectum behind and the prostate gland or vagina in front. The inferior convex surface of the muscle forms the inner wall of the ischio-rectal fossa. Its posterior edge is overlapped by the ischio-coccygeus; its anterior edge is in contact with the posterior layer of the triangular ligament.

The **levator ani** is divisible into four parts—pubo-rectalis, pubo-coccygeus, ilio-coccygeus, and ilio-sacralis. The **pubo-rectalis** (levator prostatæ) is the part inserted into the central point of the perineum. The **pubo-coccygeus** is the part inserted into the anus and the ano-coccygeal raphe, and the **ilio-coccygeus** and **ilio-sacralis** are represented by the fibres attached to the sacrum and coccyx. The first two are best developed; the last two series of fibres are the most rudimentary. These several parts of the muscle represent the remains of the flexor caudæ of tailed animals.

The **ischio-coccygeus** is a rudimentary muscle overlapping the posterior border of the levator ani. It **arises** from the ischial spine and the small sacro-sciatic ligament, and is **inserted** into the sides of the lower two sacral and upper two coccygeal vertebræ. The muscle is separated from the rectum by the visceral pelvic fascia, and is in contact externally with the sacro-sciatic ligaments.

Nerve-Supply.

The **levator ani** is supplied from two sources: by the perineal (muscular) branch of the pudic nerve, and, on its pelvic surface, by special branches from the third and fourth sacral nerves. The **ischio-coccygeus** is supplied on its pelvic surface by the third and fourth sacral nerves.

Actions.

(1) The levator ani and ischio-coccygeus serve to uphold and slightly raise the pelvic floor. (2) They are likewise capable of producing slight flexion of the coccyx. (3) The anterior fibres of the levator ani, in the female, sweeping round the vagina, compress its walls laterally, and along with the sphincter vaginæ, help to voluntarily diminish the lumen of the tube. (4) The same part of the muscle in the male elevates the prostate gland (levator prostatæ). (5) The chief action of the levator ani is in *defæcation*. Along with the external sphincter it acts as a sphincter of the rectum, closing the anal canal. During defæcation the muscle draws upwards the anus over the fæcal mass, and so assists in its expulsion. (6) *In parturition*, in the same way, the muscle, contracting below the descending fœtal head, retards delivery. Contracting on the fœtal head, it draws upwards the pelvic floor over the fœtus, and so assists delivery.

THE DEVELOPMENT AND MORPHOLOGY OF THE SKELETAL MUSCLES.

Our knowledge of the development and morphology of the muscular system is very incomplete. It has already been shown, in the chapter on general embryology, that the mesoblast on either side of the embryonic medullary tube separates into three main parts—the **myotome**, **nephrotome**, and **sclerotome** or **lateral plates** (somatopleure and splanchnopleure).

The **myotomes** are probably directly or indirectly the source of the striated muscles of the whole body. Each consists at first of a quadrilateral bilaminar mass, resting against the medullary tube and notochord on either side. The cleft between its two layers represents the remains of the cœlomic cavity. In the early stages of embryonic life the growth of the myotome is rapid. On its inner side masses of cells arise, which grow inwards and surround the medullary tube and notochord to form the foundation of the vertebral column. On its outer side cells appear to be given off which participate in the formation of the cutis vera. At the same time the dorsal and ventral borders of the myotome continue to extend, and present extremities (growing points) with an epithelial structure for a considerable period. *On the dorsal side* it overlies the medullary tube, and gives rise to the muscles of the back; while by its *ventral extension*, which traverses the somatopleuric mesoblast in the body wall, it produces the lateral and ventral muscles of the trunk. By an inward extension it probably gives rise also to the hypaxial muscles of the neck and loin. The cells of the inner layer of the myotome are responsible for the formation of the muscle fibres. The cells elongate in a direction parallel to the long axis of the embryo, and give rise, by fusion with the cells of neighbouring myotomes, to the columns and sheets of muscles of the back and trunk. For the most part (*e.g.* back and abdomen) the originally segmental character of the muscular elements is lost by the more or less complete fusion of adjacent myotomes. The intercostal muscles, however, are the direct derivatives of individual myotomes.

Muscles of the Limbs.—In fishes and (doubtfully) reptiles there is evidence that the myotomes are concerned in the formation of the limb-muscles by their extension into the limb-bud in a manner similar to that described for the trunk. In birds and mammals, however, in which the limb-bud arises as an undifferentiated, unsegmented mass of mesoblastic tissue, partly from the mesoblast surrounding the notochord, and partly from the somatopleuric mesoblast, the myotomes stop short at the root of each limb, and do not penetrate into its substance. Instead, the muscular elements of the limb take

origin independently as *double dorsal* and *ventral strata* of fusiform cells on the dorsal and ventral surfaces of the limb-bud. These strata are *unsegmented*; they are grouped around the skeletal elements of the limb, and they gradually become differentiated into the muscle masses and individual muscles of the limb.

Muscles of the Head.—Notwithstanding the obscurity and complexity of this

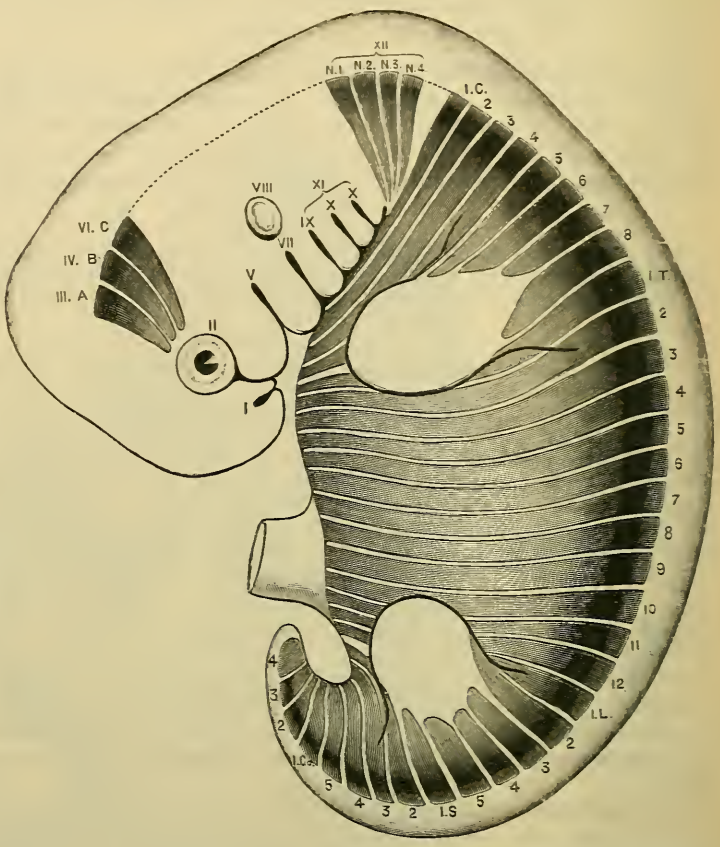


Fig. 352.

Scheme to Illustrate the Disposition of the Myotomes in the Embryo in Relation to the Head, Trunk, and Limbs.

A, B, C, First three cephalic myotomes; N, I, 2, 3, 4, Last persisting cephalic myotomes; C., T., L., S., Co., The myotomes of the cervical, thoracic, lumbar, sacral, and caudal regions; I., II., III., IV., V., VI., VII., VIII., IX., X., XI., XII., refer to the cranial nerves and the structures with which they may be embryologically associated.

subject, it appears certain that *at least two series* of elementary structures are concerned in the formation of the muscles of the head and face—the **cephalic myotomes** and the muscular structure of the **branchial arches.**

The number of myotomes originally existing in the region of the head is not known, although it is stated with some authority that nine is the perfect number. The *first three* are described as persisting in the form of the ocular muscles, the *last three* in relation to the muscles of the tongue, while the *three intervening myotomes* disappear.

The following table shows the possible fate of the cephalic myotomes:—

First, Superior, internal and inferior recti, obliquus inferior, levator palpebræ superioris.
Second, Obliquus superior.
Third, Rectus externus.
Fourth, *Fifth* and *Sixth*, Absent.
Seventh, *Eighth*, } Muscles of the tongue.
Ninth, *Tenth* (*first cervical*) } Muscles connecting the cranium and shoulder girdle.

The **mesoblastic tissue of the branchial arches** is probably concerned in the production of the following muscles of the face and neck:—

First (*mandibular*) *arch* . .	Muscles of mastication.
Second (*hyoid*) *arch* . . .	Platysma myoides and facial muscles. Muscles of the soft palate. Stapedius, stylo-hyoid, and digastric.
Third (*thyro-hyoid*) *arch* . .	Stylo-pharyngeus. Superior constrictor.
Fourth and Fifth (*branchial*) *arches*	Middle and inferior constrictors. Muscles of the larynx.

THE NERVOUS SYSTEM.

THE BRAIN AND SPINAL CORD, WITH THEIR MENINGES.

By D. J. Cunningham.

The nervous system connects the various parts of the body with each other and co-ordinates them into one harmonious whole. Its relatively great bulk and its extreme complexity constitute two of the most distinctive structural features of man. It consists of two parts, viz. the cerebrospinal nervous system and the sympathetic nervous system.

The **sympathetic nervous system** is composed of a chain of serially disposed ganglia, bound to each other by intervening nervous cords, and placed one on either side of the vertebral column. In addition to these gangliated cords, the sympathetic system includes certain dense plexuses of nerves and numerous scattered ganglia. The whole is most intimately connected with the cerebrospinal nervous system, and both have apparently a common developmental origin. The separation of the nervous system into the two leading subdivisions of sympathetic and cerebrospinal is therefore of a somewhat arbitrary kind.

The **cerebrospinal nervous system** consists of the brain, which very nearly completely fills the cranial cavity, and the spinal cord or spinal marrow, which only partially fills the vertebral canal. These are continuous with each other, and together constitute the cerebrospinal axis. Attached to the brain and spinal cord are the numerous nerves which bring the various parts of the body into connexion with the central nervous axis. There are thirty-one pairs of symmetrically disposed **spinal nerves** attached to the sides of the spinal cord. Each of these nerves is connected to the side of the cord by a **ventral** or **anterior** and a **dorsal** or **posterior root**, and the dorsal root is distinguished by presenting a distinct oval swelling, termed a **spinal ganglion**, on that part of its course immediately internal to the place where the two roots unite to form the **spinal nerve-trunk** (Fig. 365, p. 453).

The **cranial nerves** are twelve in number on each side, but one only (viz. the fifth or trigeminal) presents a double-rooted attachment similar to a spinal nerve Several, however, possess ganglia in every respect comparable with the ganglia on the dorsal roots of the spinal nerves. These are the fifth or trigeminal, the seventh or facial, the eighth or auditory, the ninth or glosso-pharyngeal, and the tenth or vagus cranial nerves.

CEREBROSPINAL NERVOUS SYSTEM.

The brain and spinal cord are composed of two substances which present a different appearance to the eye, and which are distinguished by the terms **white matter** and **gray matter**. The difference in colour between these two substances depends not only upon the different elements which enter into their formation, but also upon the fact that the gray matter is the more vascular of the two. The white matter is chiefly composed of nerve-fibres, whilst the essential constituents of the gray matter are nerve-cells which give origin to nerve-fibres. An all pervading matrix termed the neuroglia forms the bed in which the nerve-fibres and

nerve-cells lie, and is present both in the gray and the white matter. The elements, therefore, which constitute nervous tissue are nerve-cells, nerve-fibres, and neuroglia.

Nerve-fibres.—Nerve-fibres arranged in bundles of greater or less bulk form the nerves which pervade every part of the body. They also constitute the greater part of the brain and spinal cord. Nerve-fibres are the conducting elements of the nervous system; they serve to bring the nerve-cells into relation both with each other and with the various tissues of the body.

There are different varieties of nerve-fibres, but in all the leading and essential constituent is a delicate thread-like band, termed the **axis-cylinder.** The difference between individual fibres depends upon the fact that in some cases the axis-cylinder becomes invested by one or two coats, whilst in other cases it remains naked. When the axis-cylinder is coated on the outside by a more or less thick sheath of a fatty substance termed **myelin,** it is said to be a myelinated or medullated fibre. When the coating of myelin is absent, the fibre is termed a non-myelinated or a non-medullated fibre. A second sheath—thin, delicate, and membranous, and placed externally—may also be present in both cases. It is termed the **primitive sheath** or the **neurolemma.** From a structural point of view, therefore, four different forms of nerve-fibre may be recognised:—

Fig. 353. Nerve-fibre from a Frog (after v. Kölliker).

Non-medullated { 1. Naked axis-cylinders.
2. Axis-cylinders with primitive sheaths.
Medullated { 3. Primitive sheath absent.
4. Primitive sheath present.

Every nerve-fibre near its origin and as it approaches its termination is unprovided with sheaths of any kind, and is simply represented by a non-medullated naked axis-cylinder. The fibres of the olfactory nerves afford us an example of non-medullated fibres furnished with a primitive sheath.

Medullated fibres are present in greater quantity in the cerebro-spinal system than non-medullated fibres. Thus all the nerves attached to the brain and cord, with the exception of the olfactory and optic, are formed of medullated fibres provided with a primitive sheath; whilst the entire mass of the white substance of the brain and cord, and also the optic nerves, are formed of medullated fibres devoid of a primitive sheath.

It is important to note that the distinction between the medullated and non-medullated fibres is not one which exists throughout all stages of development. As will be presently pointed out, every fibre is a direct outgrowth from a cell, and in the first instance it is not provided with a medullary sheath. Indeed, it is not until about the fifth month of fœtal life that those fibres which are to form the white substance of the cerebrospinal axis begin to acquire their coating of myelin. Further, this coating appears in the fibres of different strands or tracts at different periods, and a knowledge of this fact has enabled the anatomist to follow out the connexions of the tracts of fibres which compose the white matter of the brain and cord.

But it may be asked: How does a nerve-fibre arise and how does it end? Every fibre is directly continuous by one extremity with a nerve-cell, whilst its opposite extremity breaks up into a number of ramifications, all of which end freely in relation to another nerve-cell, or in relation to certain tissues of the body, as, for example, to muscle-fibres or to the epithelial cells of the epidermis. The length of nerve-fibres, therefore, varies very greatly. Some fibres are short and merely bring two neighbouring nerve-cells into relation with each other: others travel long distances. Thus a fibre arising from one of the motor cells of the lower end of the spinal cord may, after leaving the cord, extend to the most outlying muscle in the sole of the foot before it reaches its destination. But even when a fibre does not leave the central axis a great length may be attained, and cells

situated in the motor area of the cortex of the cerebrum give origin to fibres which pass down to the lower end of the cord.

Physiologists classify the fibres which form the nerves into two sets, afferent and efferent. **Afferent nerve-fibres** conduct the impulse of impressions from the peripheral organs into the central nervous system; and as a change of consciousness, or, in other words, a sensation is a frequent result, these fibres are often called *sensory*. **Efferent nerve-fibres** carry impulses out from the brain and cord to peripheral organs. The majority of these fibres go to muscles and are termed *motor*; others, however, go to glands and are called *secretory*; whilst some are *inhibitory* and serve to carry impulses which restrain or check movement or secretion. As previously stated, the spinal nerves are each attached to the cord by a ventral or anterior root, and a dorsal or posterior root; the fibres composing the former are efferent; whilst the fibres of the posterior root are almost entirely afferent.

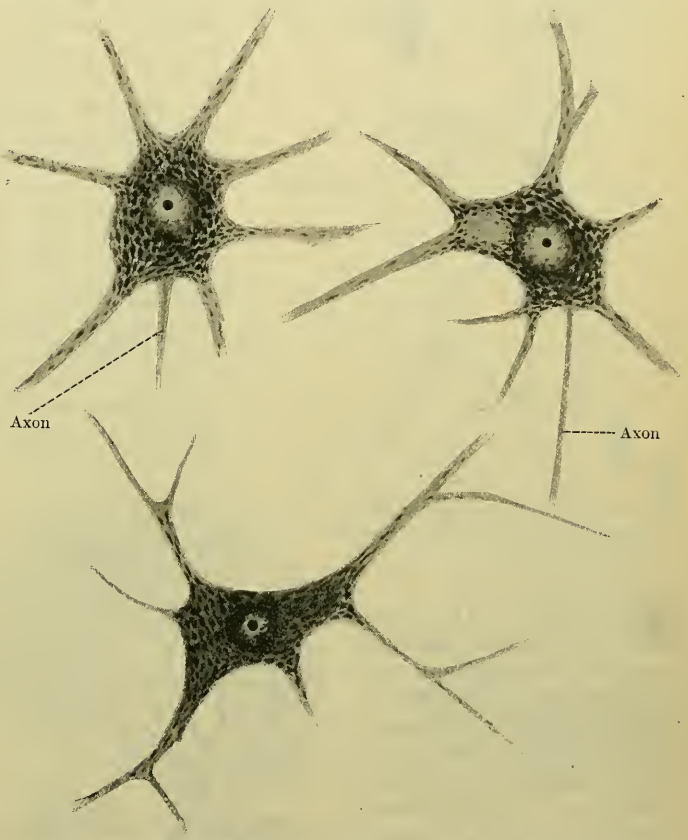


Fig. 354.—Three Nerve-Cells from the Anterior Horn of Gray Matter of the Human Spinal Cord.

Nerve-cells.—The nerve-cells constitute the active and all-essential elements of nerve-tissue. At the very start it is necessary to draw a broad distinction between the ganglionic cells, which are found in the spinal ganglia, and the cells which are so plentifully scattered through the gray matter of the brain and cord. They differ not only in their mode of origin and in their subsequent development, but also in the connexions of the nerve-fibres to which they give origin.

Nerve-cells of the Brain and Cord.—The cells in the gray matter of the cerebrospinal axis are variable both in size and form. Some are relatively large, as, for example, certain of the pyramidal cells of the cerebral cortex and the motor cells in the gray matter of the cord, which almost come within the range of unaided vision; others are exceedingly minute, and require a high power of the microscope to bring them into view. The cell consists of a protoplasmic nucleated body, from which certain processes proceed. One process is termed the **axis-cylinder process** or **axon**; and as a rule it is easily distinguished from the others, which are collectively called the **protoplasmic processes of Deiters**, or the **dendrites**.

The **axon** presents a uniform diameter and a smooth and even outline. It gives off in its course fine collateral branches, but does not suffer thereby any marked diminution in its girth. The most important point to note in connexion with the axon, however, is the fact that it becomes continuous with the axis-cylinder of a nerve-fibre. The significance of this is obvious, and will become more striking

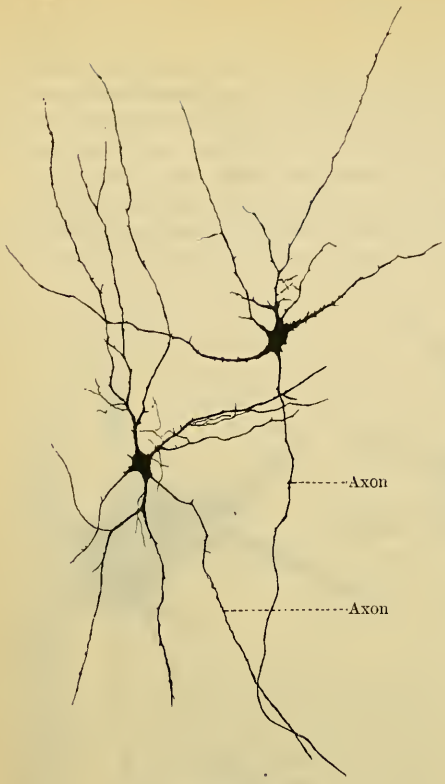


Fig. 355.—Two Multipolar Nerve-Cells, from a specimen prepared by the Golgi method.

when the development of the nerve-cells is studied. The axon then is simply a nerve-fibre, and in certain circumstances it assumes, as already stated, one or two investing sheaths. The axon may run its entire course within the substance of the brain or cord either for a short or a long distance, or it may emerge from the brain or cord in one of the cranial or spinal nerves as the essential part of an efferent nerve-fibre, and run a variable distance before it finally reaches the peripheral structure in relation to which it ends. The axon and the collaterals which spring from it terminate either in small button-like swellings or knobs, or more frequently in terminal arborisations, the extremities of which are free and are furnished with exceedingly small terminal varicosities. In those cases where the axon or its collaterals end within the brain or cord, some of the terminal arborisations interlace with the dendrites of nerve-cells, whilst others are twined around the bodies of other cells. In the latter case the interlacement may be so close and complete that it almost presents the appearance of an enclosing basket-work. In cases where the axon emerges from the cerebrospinal axis its terminal arborisation ends in relation to a muscle-fibre or some other tissue in the manner already referred to. In all cases, however, it would appear that the terminal branches of the axon, no matter how complicated the connexion may seem, are free, and that the connexion is simply one of contact or contiguity, and not one of continuity.

Held maintains that, although at first the terminal arborisations of an axon are quite free, in the process of growth and development they exhibit a tendency to become fused with the dendrites and even the bodies of other nerve-cells.

Fig. 356. — Nerve-Cell from Cerebellum (Cell of Purkinje) showing the branching of the Dendritic Processes (from a lantern slide by Professor Symington).

The **dendrites**, or protoplasmic processes of the nerve-cell, are thicker than the axon, and present a rough-edged irregular contour. They divide into numerous branches, and these gradually, as they pass from the cell-body, become more and more attenuated until they finally end in free extremities. The branching of the dendritic processes sometimes attains a marvellous degree of complexity (Fig. 356), but except in exceptional circumstances, there is no *anastomosis* between the dendrites of neighbouring cells, or between the dendrites of the same cell. It would appear, therefore, that nothing in the shape of a network is formed by these processes.

In the chapter upon Embryology it has been shown that in the early condition of the cerebrospinal axis the brain and cord consist simply of a tube (p. 21). The wall of this tube is formed of a single layer of tall columnar neuro-epithelial cells,

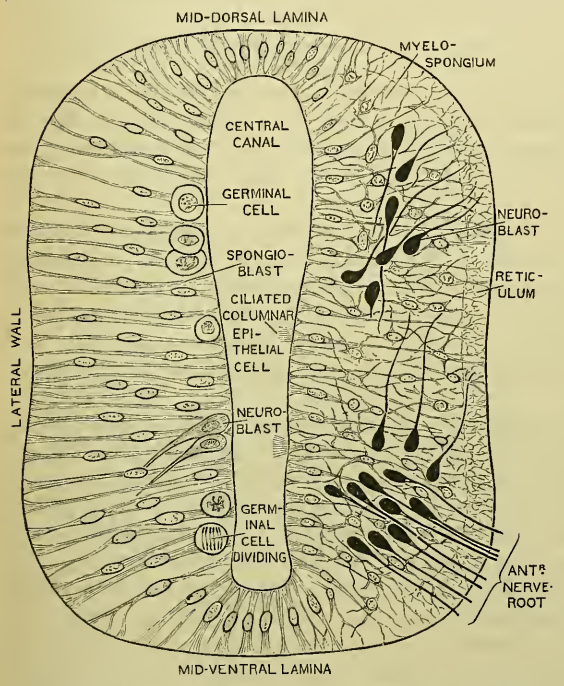


FIG. 357.—TRANSVERSE SECTION THROUGH THE EARLY NEURAL TUBE, diagrammatically represented (Alfred H. Young).

The left side of the section exhibits an earlier stage of development than the right side.

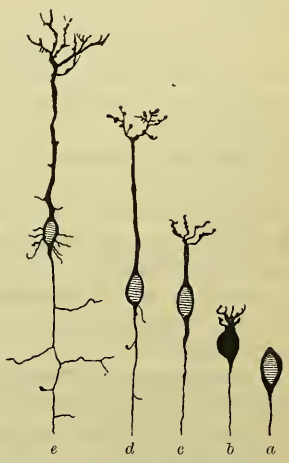


FIG. 358. — THE DEVELOPMENTAL STAGES EXHIBITED BY A PYRAMIDAL CELL OF THE BRAIN (after Ramón y Cajal).

a, Neuroblast with rudimentary axon, but no dendrites; *b* and *c*, The dendrites beginning to sprout out; *d* and *e*, Further development of the dendrites and appearance of collateral branches on the axon.

and in its deepest or most internal part large round cells make their appearance in the intervals between the epithelial columns. These new cells are termed the **germinal cells**, and from them the nerve-cells are derived. They are present in considerable numbers, and towards the fourth week of embryonic life they form an almost continuous layer. Although these cells ultimately become nerve-cells they are absolutely without processes in their early state, and therefore at this period, although there is a nervous system, there are, as His remarks, no nerves. In course of time, and as the wall of the neural tube thickens, the germinal cells begin to migrate in an outward direction. They leave the deep part of the wall of the neural tube and proceed to take up the positions they occupy in the gray matter of the cord and brain of the adult. These migrating cells assume a pyriform shape, and are termed **neuroblasts**. The drawn-out portion or stalk of the pear-shaped neuroblast represents the early axon, and this continues to grow and increase in length until it ultimately attains the terminal relations characteristic of the adult. The study of embryology presents few more remarkable phenomena than the manner in which this axon grows out, and, in the efferent nerve-fibres, emerges

from the central axis, and yet pursues its allotted path with the most unerring exactitude and precision until it ultimately reaches the nerve-cell or the peripheral tissue element with which it becomes associated. The growing point of both it and its collaterals is slightly bulbous, and it is out of this that the terminal arborisation is formed.

This conception in regard to the outgrowth of the axon in the case of the peripheral nerve-fibres has not been allowed to pass unchallenged, and it must be admitted that certain facts recently observed militate against it.

Whatever opinion may be held in regard to the developmental origin of the axis-cylinder and medullary sheath of a peripheral nerve-fibre, there is every reason for the belief that the neurolemma is mesodermic in its origin, and is therefore formed from cells outside the ectodermic neural tube. There are some who think that the axis-cylinder is secreted *in situ* by a chain of these cells, whilst others consider that the mesoblastic cells of a nerve-fibre merely constitute a cellular tube through which the growing axon worms its way to its destination, and perhaps also supply the pabulum necessary for its growth.

The dendritic processes of the nerve-cell appear at a later period than the axon. The surface of the neuroblast becomes rough and then somewhat spiny. By the growth and subdivision of these spiny projections the dendrites are formed. As His remarks, the nerve-cell is therefore the genetic centre from which all the parts of a nervous element proceed.

It must now be clear that each nerve-cell is a unit which is separate and distinct from the nerve-cells which lie around it. Further, it is obvious that it is wrong to consider the nerve-cell as something apart from the nerve-fibre. The nerve-cell with its dendrites and axon, however wide-spreading these processes may be, constitutes an independent system to which the term **neuron** is applied, and the only relation which it has with other neurons or with peripheral tissues is one of contact.

Ganglionic Nerve-Cells.—The ganglionic neurons found in the ganglia of the cranial nerves and in the ganglia on the dorsal roots of the spinal nerves have a different origin, and present many points of contrast with neurons in the gray matter of the brain and cord. As already indicated in the chapter on Embryology (p. 21) the ganglia in question are derived from the neural crest. The cells forming these ganglionic masses are somewhat oval in form, and from either extremity or pole a process grows out, and the neurons in this manner become bipolar. These processes are distinguished as central and peripheral, according to the direction which they take. The central processes grow inwards, and penetrate the wall of the neural tube. In the region of the spinal cord they form almost the whole of the fibres which enter into the composition of the dorsal roots of the spinal nerves. In the substance of the cerebrospinal axis they give off numerous collaterals, and after a course of varying extent they end, after the manner of an axon, in terminal arborisations, which enter into relationships of contact with certain nerve-cells in the cerebrospinal axis. The peripheral processes grow outwards along the path of the particular nerve with which they are associated, and they finally establish peripheral contact relations. Thus, to take one example: the majority of the fibres which go to the skin break up into fine terminal filaments, which end freely between the epithelial cells of the epidermis. The two processes of a ganglion cell, therefore, form the afferent fibres of the cerebrospinal nerves, and constitute the path along which the influence of peripheral impressions is conducted towards the brain and cord. The body of the cell is as it were interposed in the path of such impulses.

But the original bipolar character of these cells, with very few exceptions (ganglia in connexion with the auditory nerve and the bipolar nerve-cells in the olfactory mucous membrane), gradually undergoes a change which ultimately leads to their transformation into unipolar cells. This is brought about by the tendency which the cell-body has to grow to one side, viz. the side towards the surface of the ganglion (v. Lenhossek). This unilateral growth leads to a gradual approximation of the attached ends of the processes, and finally to a condition in which they appear to arise from the extremity of a short common stalk in a T-shaped manner

(Fig. 360). It is interesting to note that in certain fish the original bipolar condition of these cells is retained throughout life without change.

Both the central and peripheral processes of these ganglionic cells become the axis-cylinders of nerve-fibres, which, acquiring a medullary sheath, belong therefore to the medullated variety. From this it might very naturally be thought that the ganglionic neuron, with its two axons and no typical dendrites, is a nervous unit very different from a neuron in the gray matter of the cerebrospinal axis. It is believed by some, however (van Gehuchten and Cajal), that the peripheral process, in spite of its enclosure within a medullary sheath, and though presenting all the characters of a true axon, is in reality a dendrite. If this be the case, the morphological difference between a dendrite and an axon disappears, and van Gehuchten's functional distinction alone remains characteristic, viz. that the axon is *cellulifugal* and conducts impulses away from the cell, whilst the dendrites are *cellulipetal* and conduct impulses towards the cell.

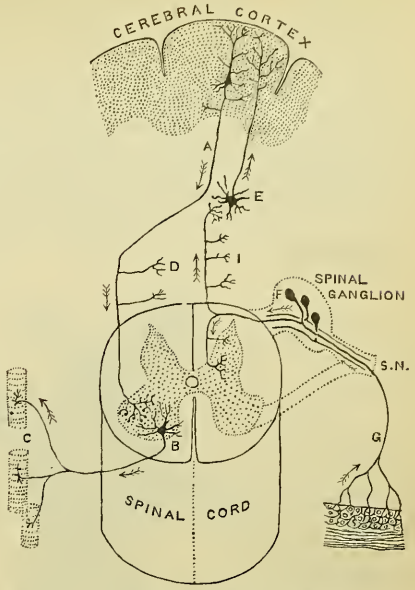


Fig. 359.—Diagram of the Connexion established by a Ganglionic and a Motor Neuron (Ramón y Cajal).

A. Fibre coming down from a pyramidal cell in the motor area of the cerebral cortex.
B. Motor cell in gray matter of spinal cord.
C. Muscle-fibres.
D. Collateral branch from the pyramidal fibre.
E. Cell in the medulla oblongata sending its axon upwards to the cerebral cortex.
F. Cells in the spinal ganglion.
G. Peripheral process of ganglionic cell ending in skin.
I. Collateral branches of central process of ganglionic cell.
S.N. Spinal nerve.

In the foregoing brief account of the elements which build up the nervous system, the neuron doctrine, as it has been enunciated by Waldeyer, has been followed. The observations of Ramón y Cajal and His form the foundation upon which this doctrine mainly rests, although it should not be forgotten that many other anatomists, amongst whom may be mentioned v. Kölliker, van Gehuchten, and v. Lenhossek, have by their investigations greatly strengthened the conception. Two primary considerations may be considered to constitute its leading support: (1) the absolute independence of the early nerve-cell or neuroblast and its processes, as was first clearly shown by His; (2) the fact that when nerve tissue is treated by the Golgi method or by the vital methylene blue method no continuity of any kind can be observed between neighbouring cells, although the processes of the cells can apparently be traced to their ultimate divisions. Further, it should be noted that the neuron doctrine receives strong support from pathological observations, and that before it assumed concrete form ideas of a somewhat similar kind were present in the minds of pathologists.

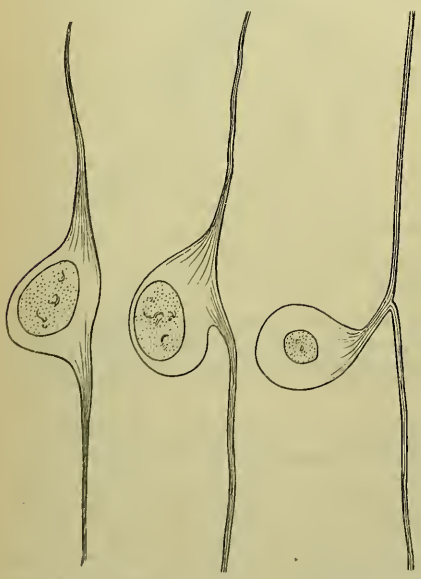


Fig. 360.—Three Stages in the Development of a Cell from a Spinal Ganglion.

Still the neuron theory is not accepted by several leading Histologists. Apáthy, Nissl, and Bethe at the present moment form a powerful combination against it. It is therefore necessary to indicate the views entertained by these observers.

More than thirty years ago Max Schultze called attention to the fact that the axis-cylinder of a nerve-fibre is composed of exceedingly fine fibrils[1] which, when traced to the cell from which the fibre takes origin, are there seen to enter the cell-body and spread out within it. By more delicate methods of research, Apáthy and Bethe have been able to place this early observation of Schultze beyond the realm of doubt. Apáthy, who worked chiefly at the invertebrate nervous system, not only traced the neuro-fibrillæ through the cell-body but

[1] It may be mentioned that Remak, the discoverer of the axis-cylinder in 1838, stated that it was finely striated in the longitudinal direction.

into all its processes, and he believes that he has been able to follow them beyond these into a delicate fibrillar interlacement which constitutes a bond of union between all the nerve-cells of the nervous system. Bethe's observations have been carried out in vertebrates. Two illustrations from his book are reproduced in Fig. 361. The cell represented in A is from the gray matter of the anterior horn of the human spinal cord, and the relation presented by the neuro-fibrils within the cell and to its various processes are very clearly depicted. The axon appears to receive a contribution of neuro-fibrillæ from all the dendritic processes; this, according to Bethe, is characteristic of the great majority of nerve-cells. In the cells indicated by the letter B, which are from the cerebral cortex of man, it will be noticed that the axons as they leave the cell become exceedingly fine and delicate, and the neuro-fibrillæ which compose them are so closely packed together that all trace of their individual existence disappears. When the medullary sheath is assumed by the fibre the neuro-fibrillæ of the axis-cylinder again become apparent.

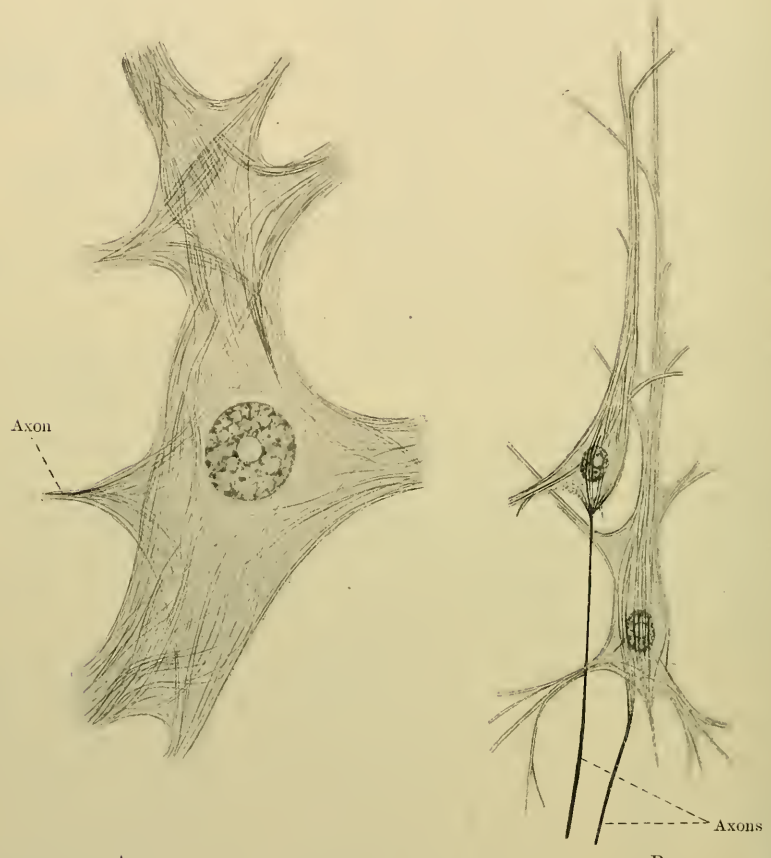


Fig. 361.—Nerve Cells as depicted by Bethe.

A, A cell from the anterior horn of gray matter of the spinal cord of man.
B, Two cells from the human cerebral cortex.

In vertebrates Bethe has not been able to trace the neuro-fibrils into an all-pervading fibrillar network such as Apáthy has described as binding the various nerve elements together in the invertebrates, but he has followed them into the finest of the dendritic branchings, and he assumes that the connecting network exists in the higher as well as in the lower members of the animal kingdom.

This conception of the structure of the axon renders the giving off by the nerve-fibre of collateral branches and also its terminal splitting or arborisation, matters which can be the more easily understood.

On the strength of the observations detailed above, Apáthy, Bethe, and Nissl, all of whom are authorities who deserve the highest degree of attention, have assailed the neuron theory. Apáthy has advanced the hypothesis that the all-pervading fibrillar interlacement, which streams continuously throughout the whole nervous system and is found not only in the cell and its processes but also in the form of a connecting network outside the cells, is the essential part of the nervous system and not the so-called independent neurons of the neuron theory. It is also contended that axons or axis-cylinders may arise in two ways: (1) directly from the nerve-cells; (2) indirectly from the neuro-fibrillar network between the nerve-cells.

In a striking address recently delivered by Professor Waldeyer to the Royal Society of Edin-

burgh the essential points of the neuron doctrine were vigorously maintained and several new preparations by Ramón y Cajal and Beilschowsky were demonstrated. In the latter the neuro-fibrillæ were seen to enter the cell-body, spread out and break up into a plexus within it, but none could be detected pursuing an uninterrupted course right through the cell and then passing out from it.

As Edinger remarks, investigation in the immediate future will be largely concerned in the attempt to further elucidate the following questions: (1) Are the connexions between neurons merely those of contact? (2) Do the fibres which proceed from one cell fuse with the constituent parts of another neuron? (3) Do the neuro-fibrillæ form an inter-connecting network between the nerve-cells, and do axons or axis-cylinders arise from such a network? It is questionable even if the last two of these queries are answered more or less in the affirmative whether it will be necessary to abandon the essential points in the neuron theory.

Since the foregoing has been printed an instructive monograph on the subject has been published by Professor Gustaf Retzius ("Punktsubstanz 'Nervöses Grau' und Neuronenlehre," *Biologische Untersuchungen*, Neue Folge, xii.).

Neuroglia.—The neuroglia is the supporting tissue of the cerebrospinal axis. It may be considered to include two different forms of tissue, viz. the lining ependymal cells and the neuroglia proper. We place these under the one heading, seeing that in all probability they both have a common developmental origin.

The **ependymal cells** are the columnar epithelial cells which line the central canal of the spinal cord and the ventricles of the brain. In the embryonic condition a process from the deep extremity of each cell traverses the entire thickness of the neural wall and reaches the surface. It is not known whether this process exists in the adult.

The **neuroglia proper** is present in both the white and the gray matter of the cerebrospinal axis. It constitutes an all-pervading basis substance, in which the various nerve elements are embedded in such a way that they are all bound together into a consistent mass and are yet all severally isolated from each other. Neuroglia consists of cells and fine filaments. The fibrils are present in enormous numbers, and by their interlacements they constitute what appears to be a fine feltwork. At the points where the fibrils intercross may be seen the flattened glial cells. Whilst the neuroglia is for the most part intimately intermixed with the nerve elements, there are in both brain and cord certain localities where it is spread out in more or less pure layers. Thus upon the surface of the brain and of the spinal cord there is such a layer; likewise beneath the epithelial lining of the central canal and of the cavities of the brain there is a thin stratum of neuroglia.

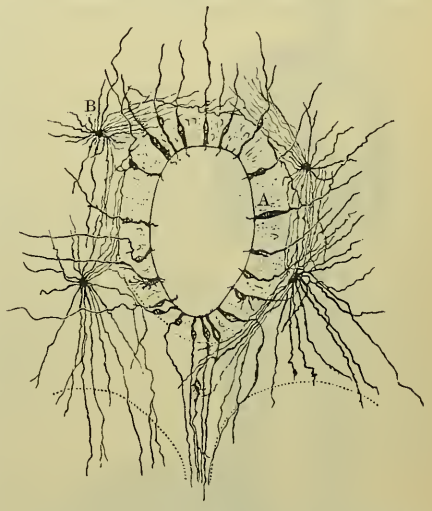


Fig. 362.—Section through the Central Canal of the Spinal Cord of a Human Embryo, showing Ependymal and Neuroglial Cells (after v. Lenhossek).
A, Ependymal cell. B, Neuroglial cell.

The ependymal cells are derived from the original neuro-epithelial cells of the early neural tube, and in all probability the neuroglia proper has a similar origin. They both, therefore, are products of the ectoderm.

Summary.—1. The cerebrospinal nervous system is composed of two parts, viz. (*a*) a **medullary part**, consisting of the brain and spinal cord, with the efferent nerve-fibres which pass out from them; (*b*) the **ganglionic part**, with the afferent nerve-fibres.

2. Each of these parts has a different origin and is composed of neurons which possess characteristic features.

3. The ganglionic neurons are derived from the primitive cells of the neural crest, and have each one process which divides into two. Of these the central division enters the cerebrospinal axis and probably represents the axon, whilst the peripheral division, which becomes connected with a peripheral part, may provisionally be regarded as a dendrite. The central fibres from the ganglionic cells

in the region of the cord form the dorsal or posterior roots of the spinal nerves. These roots have thus an origin outside the cord, and grow into its substance in the process of development in the same manner that the roots of a plant strike into the soil.

4. The cerebrospinal neurons are derived from the germinal cells in the wall of the early neural tube. Certain of these furnish efferent nerve-fibres, which issue from the cord in separate bundles termed the anterior or ventral roots of the spinal nerves. In the case of the cranial nerves, however, with the exception of the trigeminal and facial nerves, the efferent fibres are not thus separated from the afferent fibres at their attachment to the brain.

5. The brain and cord when studied by the naked eye are seen to be composed of white matter and gray matter. The white matter forms very nearly two-thirds of the entire cerebrospinal axis. It is composed of medullated nerve-fibres embedded in neuroglial tissue. The gray matter is composed of nerve-cells with their dendrites and axons. Some of the axons are in the form of naked axis cylinders, whilst others have a coating of medulla. Intimately intermixed with these parts is the neuroglia, which isolates them more or less completely from each other.

SPINAL CORD.

The **spinal cord** is that part of the cerebrospinal axis which occupies the upper two-thirds of the spinal canal of the vertebral column. It is an elongated cylindrical structure, slightly flattened in front and behind, which extends from the margin of the foramen magnum to the level of the lower border of the body of the first lumbar vertebra or to the upper border of the body of the second lumbar vertebra. Its average length in the male is 45 cm. and in the female 43 cm.

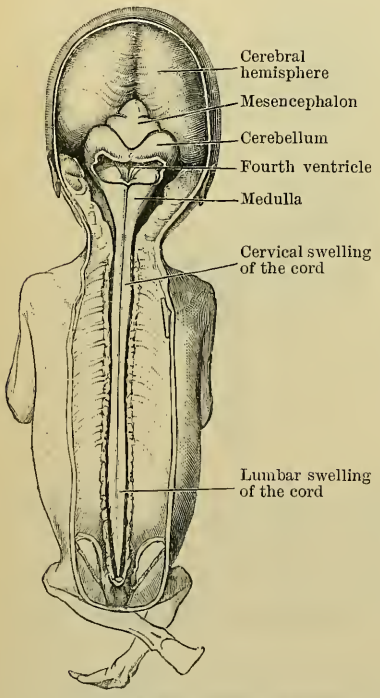


FIG. 363.—HUMAN FŒTUS IN THE THIRD MONTH OF DEVELOPMENT, WITH THE BRAIN AND SPINAL CORD EXPOSED FROM BEHIND.

A considerable amount of variation within certain limits (viz. the mid-point of the body of the last dorsal vertebra and the upper border of the body of the third lumbar vertebra) is observed in different individuals as to the precise level at which the spinal cord ends inferiorly, and in the female there would appear to be a tendency for the cord to reach a slightly lower point in the canal than in the male. Further, the relation presented by the spinal cord to the vertebral column differs in a marked degree in the fœtus and infant at different periods of development. Up to the third month of intrauterine life the cord occupies the entire length of the spinal canal; it extends downwards to the lowest limit of the canal. But from this time on, as growth proceeds, the vertebral column lengthens at a more rapid rate than the cord. The spinal cord, therefore, has the appearance of shrinking in an upward direction within its canal, and at birth its lower end is usually found to be opposite the body of the third lumbar vertebra.

The attitude assumed by the individual affects to a small degree the position of the lower end of the cord. Thus, when the trunk is bent well forwards, it is noticed that the terminal part of the cord rises slightly within its bony canal.

At the margin of the foramen magnum the spinal cord becomes continuous with the medulla oblongata of the brain, whilst below, it tapers rapidly to a point and forms a conical extremity termed the **conus medullaris**. From the end of the conus medullaris a slender glistening thread is prolonged downwards within the spinal canal, and finally anchors the spinal cord to the back of the coccyx. This prolongation receives the name of the **filum**

terminale. The diameter of the cord is very much shorter than that of the spinal canal within which it lies. A wide interval is left between its surface and the walls of its canal, and this excess of space is clearly a provision for allowing free movement of the vertebral column without producing any jarring contact between the delicate spinal cord and the surrounding bones.

Three protective membranes are wrapped around the cord. From within outwards these are termed (1) the pia mater, (2) the arachnoid mater, and (3) the dura mater. The **pia mater** is a fibrous membrane which forms the immediate investment. It is closely applied to the cord, and from its deep surface numerous fine septa penetrate into the substance of the cord. The **arachnoid mater** is an exceedingly delicate transparent membrane which is loosely wrapped around the cord so as to leave a considerable interval, termed the subarachnoid space, between itself and the pia mater, in which there is always a varying amount of cerebro-spinal fluid. Outside the arachnoid mater, the **dura mater** forms a wide, dense, fibrous, tubular sheath, which extends downwards within the spinal canal for a considerable distance beyond the conical extremity of the cord. The spinal cord is suspended within its sheath or *theca* of dura mater by two lateral wing-like ligaments, termed the **ligamenta denticulata.** These extend outwards from the sides of the cord and are attached by a series of pointed or tooth-like processes to the inner surface of the theca of dura mater. Between the wall of the spinal canal and the dura mater there is a narrow interval, which is filled up by soft areolo-fatty tissue and numerous thin-walled veins arranged in a plexiform manner.

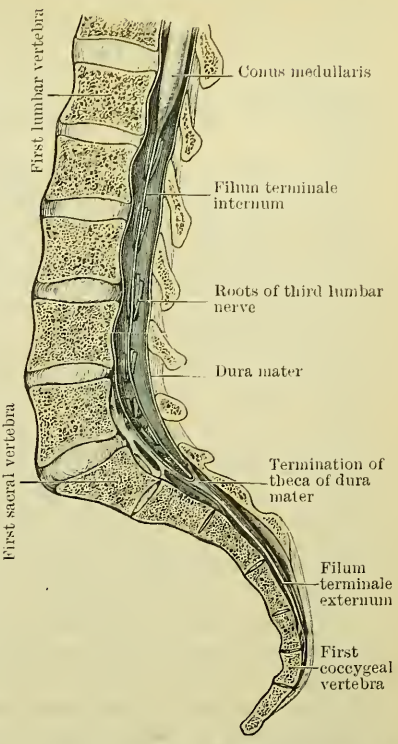


Fig. 364.—The Conus Medullaris and the Filum Terminale exposed within the Spinal Canal.

Thirty-one pairs of spinal nerves arise from the sides of the spinal cord. These are classified into eight cervical, twelve

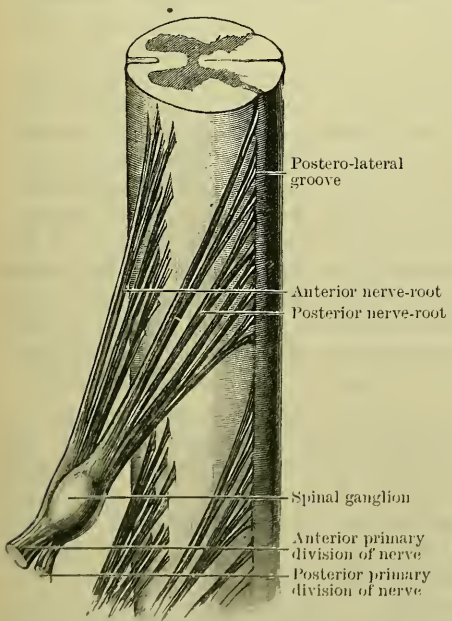


Fig. 365.—The Roots of Origin of the Seventh Dorsal Nerve (semi-diagrammatic).

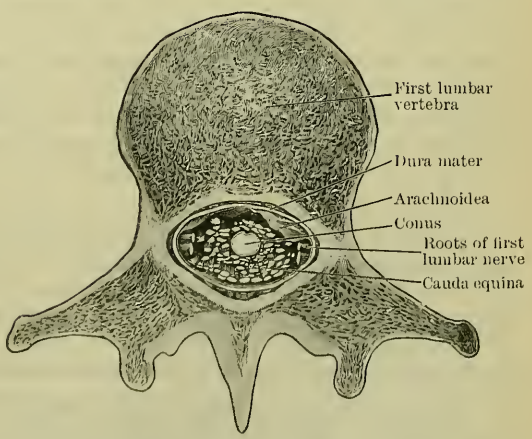


Fig. 366.—Section through the Conus Medullaris and the Cauda Equina as they lie in the Spinal Canal.

dorsal, five lumbar, five sacral, and one coccygeal; and according to the attachments of these groups of nerves the spinal cord is arbitrarily subdivided into cervical, dorsal, lumbar, and sacral regions. In employing these terms, therefore, for different districts of the cord, it must be understood that the regions are determined by the nerve attachments, and not by any direct relationship between these parts of the cord and the sections of the vertebral column which bear the same names.

Each spinal nerve is attached to the cord by a ventral and a dorsal root, and as these are traced to their central attachments they are seen to break up into a number of separate nerve fascicles or bundles, which spread out, in some cases very widely from each other, as they approach the side of the cord (Fig. 365). Each pair of nerves is therefore attached to a portion of spinal cord of some length, and such a portion, with its pair of nerves, receives the name of a "segment of the spinal cord." It must be clearly understood, however, that, in so far as the surface of the cord is concerned, there is absolutely no means of marking off one segment from another, except by the nerve attachments.

In the cervical and lumbar regions of the cord the nerve-roots are somewhat crowded together, so that little or no interval is left between the adjoining root fascicles of neighbouring nerves. In the dorsal region, however, distinct intervals may be observed, and the root fascicles are more loosely arranged. From this, it will be evident that the cord segments in different parts of the cord are not of equal length. In the cervical region the segments measure about 12 mm. in length, in the dorsal region from 20 to 24 mm., and in the lumbar region about 10 mm. The number of fascicles which attach the different nerve-roots to the cord is very different in different nerves, and is not necessarily the same in the same nerve-root in different individuals.

Owing to the great difference which exists between the length of the spinal cord and the length of the vertebral column, the farther we pass down the greater the distance becomes between the attachment of the various nerve-roots to the cord and the invertebral foramina through which the corresponding nerves leave the spinal canal. The lower nerve-roots, therefore, have to traverse the spinal canal for a considerable distance before they reach their apertures of emergence. It thus happens that the nerve-roots which spring from the lumbar and sacral regions of the cord attain a very great length and descend vertically in the lower part of the spinal canal in a bunch or leash, in the midst of which lie the conus medullaris and the filum terminale. This great bundle of nerve-roots receives the appropriate name of the **cauda equina**.

Enlargements of the Cord.—Throughout the greater part of the dorsal region, the spinal cord presents a uniform girth and a very nearly circular outline when seen in transverse section. In the cervical and lumbar regions, however, it shows marked swellings. The **cervical enlargement** (intumescentia cervicalis) is the more evident of the two. It begins very gradually at the upper end of the cord, attains its greatest breadth (12 to 14 mm.) opposite the fifth or sixth cervical vertebra, and finally subsides opposite the second dorsal vertebra. To this portion of the cord are attached the great nerves which supply the upper limbs. The **lumbar enlargement** (intumescentia lumbalis) begins at the level of the tenth dorsal vertebra, and acquires its maximum transverse diameter (11 to 13 mm.) opposite the last dorsal vertebra. Below, it rapidly tapers away into the conus medullaris. To the lumbar enlargement are attached the great nerves of the lower limbs.

These enlargements of the cord are associated with the outgrowth of the limbs. In the earlier developmental stages of the spinal cord they are not present, and they only take form as the limbs become developed. In the lower mammalia their size corresponds with the degree of development of the limbs. Thus, in the long-armed orang and gibbon, the cervical swelling stands out with a remarkable degree of prominence. It is, however, interesting to note that although in the cetacea there are no visible hind-limbs, there is nevertheless a well-marked lumbar enlargement of the cord.

Fissures and Furrows of the Cord.—When cross-sections of the spinal cord are made, it is seen to be a bilateral structure which is partially subdivided into a right and left half by two median clefts—one upon the anterior and the other upon the posterior aspect. These clefts are termed the antero-median and the postero-median fissures, and they extend along the entire length of the cord. At the same

time it must be noted that these two median clefts present many points of difference. The **antero-median fissure** (fissura mediana anterior) is for the greater part of its length much shallower than the postero-median fissure. In the cervical and dorsal regions it only penetrates for a distance corresponding to somewhat less than a third of the antero-posterior diameter of the cord. Further, the antero-median cleft is much the wider and more apparent of the two, and the pia mater dips down into it and forms a fold or reduplication within it. The **postero-median fissure** (fissura mediana posterior) in the cervical and dorsal regions penetrates into the cord until it reaches a point somewhat beyond its centre. It is extremely narrow, and contains a single septum which is derived from ependymal and neuroglial elements, and is intimately connected with the adjacent sides of the two halves of the cord, between which it intervenes. The pia mater, which invests the surface of the cord, passes continuously over the postero-median fissure and sends no prolongation of any kind into it. In the lumbar region of the cord the postero-median fissure becomes shallower, whilst the antero-median fissure deepens, and ultimately in the lower part of the cord the two fissures present a very nearly equal depth.

The two halves of the cord, which are marked off from each other by the median fissures, may show trifling differences in the arrangement of the parts which compose them; but to all intents and purposes they are symmetrical. They are joined together by a more or less broad band or commissure, which intervenes between the two median fissures.

An inspection of the surface of each lateral half of the cord brings into view a longitudinal groove or furrow, at some little distance from the postero-median cleft, which extends along the whole length of the cord. Along the bottom of this groove the fascicles of the posterior nerve-roots enter the cord in accurate linear order. It is called the **postero-lateral sulcus** (sulcus lateralis posterior). There is no corresponding furrow on the forepart of each lateral half of the cord in connexion with the emergence of the fascicles of the anterior nerve-roots. These fascicles emerge irregularly over a broad strip of the surface of the cord, which corresponds in its width to the thickness of the subjacent extremity of the anterior horn of gray matter.

The postero-lateral groove subdivides each lateral half of the cord into a small **posterior column** (funiculus posterior) and a much larger **antero-lateral column**, and it is customary to arbitrarily map off the latter into a **lateral column** (funiculus lateralis) and an **anterior column** (funiculus anterior) by a line corresponding to the emergence of the outermost fascicles of the anterior nerve-roots.

In the cervical region a distinct longitudinal groove may be observed on the surface of the posterior column. It is placed rather nearer to the postero-median than to the postero-lateral furrow, and as it is traced down into the dorsal region it gradually becomes indistinct and finally disappears. This is called the **posterior paramedian groove**, and it marks on the surface the position of a septum of pia mater which dips into the cord and subdivides the posterior column into an outer part, termed the **funiculus cuneatus** or the **column of Burdach**, and an inner portion, which receives the name of the **funiculus gracilis** or the **column of Goll**.

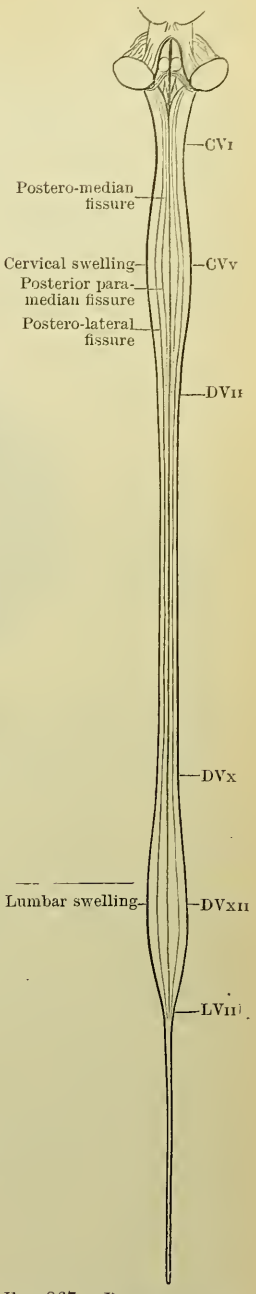


FIG. 367.—DIAGRAM OF THE SPINAL CORD AS SEEN FROM BEHIND.

CVI shows the level of the 1st cervical vertebra; CVv of the 5th cervical vertebra; DVII of the 2nd dorsal vertebra; DVx of the 10th dorsal vertebra; DVXII of the 12th dorsal vertebra; LVII of the 2nd lumbar vertebra.

Internal Structure of the Spinal Cord.

The spinal cord is composed of a central core of gray matter thickly coated on the outside by white matter. At only one spot does the gray matter come close to the surface, viz. at the bottom of the postero-lateral groove.

Gray Matter of the Cord.—The gray matter in the interior of the cord has the form of a fluted column, but it is customary to describe it as it appears in transverse sections through the cord. It then presents the appearance of the capital letter H. In each lateral half of the cord there is a semilunar or crescentic mass, shaped somewhat like a comma, the concavity of which is directed outwards and the convexity inwards. The two crescents of opposite sides are connected across the middle line by a transverse band, which receives the name of the **gray commissure** (commissura grisea). The postero-median fissure cuts through the cord until it reaches the gray commissure. The bottom of the antero-median fissure, however, is separated from it by an intervening strip of white matter, which is termed the **anterior white commissure** (commissura anterior alba). In the gray commissure may be seen the **central canal** of the cord (canalis centralis), which tunnels the entire length of the cord and is just visible to the naked eye as a minute speck. The portion of the gray commissure which lies behind the central canal is called the *posterior gray commissure* (commissura grisea posterior); whilst the portion in front receives the name of the *anterior gray commissure* (commissura grisea anterior).

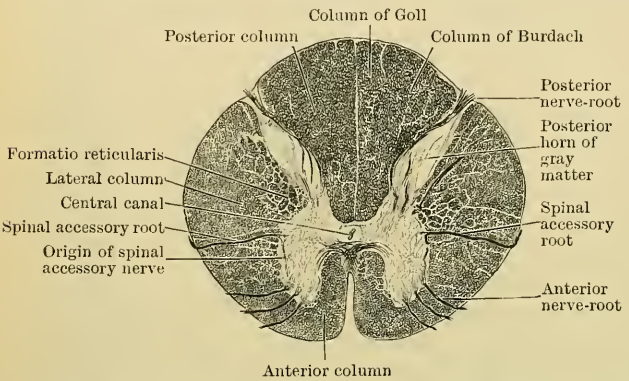


Fig. 368.—Transverse Section through the Upper Part of the Cervical Region of the Cord of an Orang. (From a specimen prepared by the Weigert-Pal method, by which the white matter is rendered dark whilst the gray matter is bleached.)

Each crescentic mass of gray matter presents certain well-defined parts. The projecting portions which extend behind and in front of the connecting transverse gray commissure are termed respectively the posterior and the anterior cornua of gray matter (columnæ griseæ). These stand out in marked contrast to each other. The **anterior cornu** (columna grisea anterior) is short, thick, and very blunt at its extremity. Further, its extremity falls considerably short of the surface of the cord and is separated from it by a tolerably thick coating of white matter. Through this the fascicles of the anterior nerve-roots, as they emerge from the gray matter of the anterior horn, pass on their way to the surface. The thickened end of the anterior cornu is called the **caput cornu**, whilst the part close to the gray commissure is termed the **cervix** or **basis cornu**. Throughout the greater part of the cord the **posterior cornu** (columna grisea posterior) is elongated and narrow, and is drawn out to a fine point, which almost reaches the bottom of the postero-lateral sulcus. This pointed extremity receives the name of the **apex cornu**; the slightly swollen part which succeeds it is the **caput cornu**; whilst the slightly constricted part adjoining the gray commissure goes under the name of the **cervix** or **basis cornu**.

The apex or tip of the posterior cornu differs considerably in appearance from the general mass of the gray matter. It is composed of a material which presents a lighter hue and has a somewhat translucent look. It is called the **substantia gelatinosa Rolandi**, and, when seen in transverse section, it exhibits a V-shaped outline and fits on the caput cornu like a cap.

A pointed and prominent triangular projection juts out from the external aspect of gray matter nearly opposite the gray commissure. This is the **lateral horn** (columna grisea lateralis), and it is best marked in the upper dorsal region (Fig.

369, B). Traced upwards it becomes absorbed in the greatly expanded anterior horn of the cervical swelling, but it reappears again in the upper part of the cord and is particularly noticeable in the second and third cervical segments; followed in a downward direction it blends with the anterior horn in the lumbar swelling and contributes to the thickening of that cornu.

The gray matter is for the most part mapped off from the surrounding white matter with a considerable degree of sharpness; but in the cervical region, on the outer aspect of the crescentic mass and in the angle between the anterior and posterior horns, fine bands of gray matter penetrate the white matter, and, joining with each other, form a network the meshes of which enclose small islands of white matter. This constitutes what is called the **formatio** or **processus reticularis**. Although best marked in the cervical region, traces of the same reticular formation may be detected in lower segments of the cord.

Characters presented by the Gray Matter in Different Regions of the Cord.—The gray matter is not present in equal quantity nor does it exhibit the same form in all regions of the cord. Indeed, each cord segment presents its own special characters in both of these respects. It is not necessary, however, in the present instance to enter into this matter with any degree of minute detail. It will be sufficient if we point out the broad distinctions which are evident in the different regions.

It may be regarded as a general law that, wherever there is an increase in the size of the nerves attached to a particular part of the cord, a corresponding increase in the amount of gray matter will be observed. It follows from this that the regions where the gray matter bulks most largely are the lumbar and the cervical swellings. The great nerve-roots which go to form the nerves of the large limb-plexuses enter and pass out from those portions of the cord. In the dorsal region there is a reduction in the quantity of gray matter in correspondence with the smaller size of the dorsal nerves.

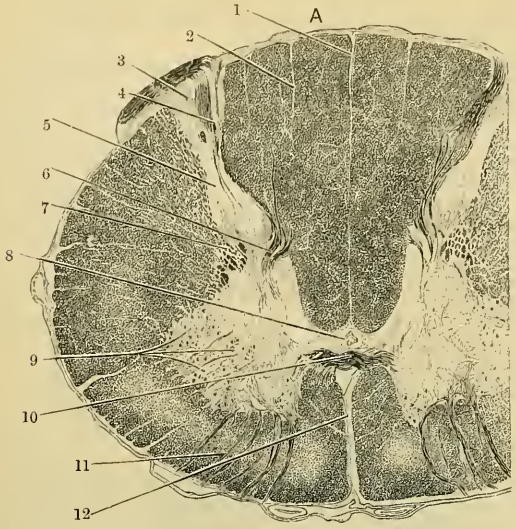
In the *dorsal region* (Fig. 369, B) both horns of gray matter are narrow, although the distinction between the anterior horn and the still more attenuated posterior horn is sufficiently manifest. In this region the lateral horn of gray matter is likewise characteristic, and the substantia gelatinosa Rolandi in transverse section is pointed and spear-shaped.

In the *upper three segments* of the *cervical region* the anterior horns of gray are not large and resemble the corresponding horns in the dorsal region. A lateral horn is also present. But in these segments (and more especially in the first and second) there is a marked attenuation of the neck of the posterior horn, and the posterior gray commissure is very broad.

In the *cervical swelling* of the cord the contrast between the two cornua is most striking; the anterior horn is of great size and presents a very broad surface towards the anterior aspect of the cord, whilst the posterior horn remains narrow. This great increase in the bulk of the anterior horn is due to a marked addition of gray matter on the outer side of the horn, and seeing that this additional matter is traversed by a greater number of fibres, it stands out, in well-prepared specimens, more or less distinctly from the part of the horn which lies to the inner side, and which may be considered to represent the entire anterior horn in the dorsal and upper cervical segments. Within this lateral addition to the anterior horn are placed those collections of cells which constitute the nuclei of origin of the motor nerves of the muscles of the upper limb. The characteristic thickening of the anterior horn of gray matter is evident, therefore, in those segments of the cord to which the nerves which enter the brachial plexus are attached, viz. the lower five cervical segments and the first dorsal segment.

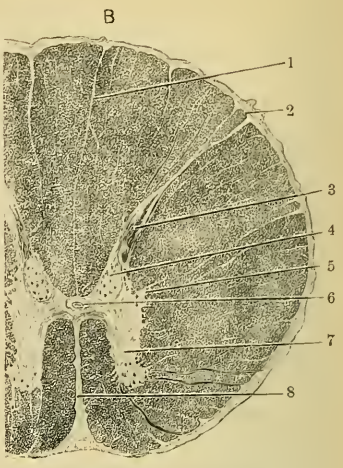
In the *lumbar swelling* the anterior horns again broaden out, and for the same reason as in the case of the corresponding horns in the cervical swelling. The nuclear masses which contain the cells from which the motor fibres which supply the muscles of the lower limbs take origin are added to the outer aspect of the horns and give them a very characteristic appearance. In this region of the cord, however, the posterior horns are also broad and capped by substantia gelatinosa Rolandi, which in transverse section presents a semilunar outline. There is

consequently no difficulty in distinguishing from an inspection of the gray matter alone between transverse sections of the cord taken from the cervical and lumbar swellings of the cord.



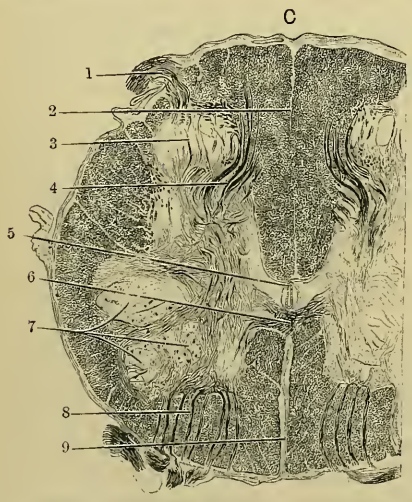
A.—Cervical region—at the level of the fifth cervical nerve. (From a specimen prepared by Dr. A. Bruce.)

1. Postero-median fissure.
2. Paramedian septum.
3. Postero-lateral groove.
4. Posterior nerve-root.
5. Substantia gelatinosa Rolandi.
6. Root-fibres entering gray matter.
7. Formatio reticularis.
8. Central canal.
9. Nuclei from which motor-fibres for muscles of upper limb arise.
10. Anterior commissure.
11. Anterior nerve-root.
12. Antero-median fissure.



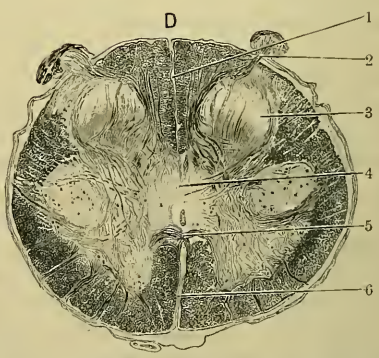
B.—Through the mid-dorsal region.

1. Postero-median fissure.
2. Postero-lateral groove.
3. Posterior cornu.
4. Posterior vesicular column of cells.
5. Lateral cornu.
6. Central canal.
7. Anterior cornu.
8. Antero-median fissure.



C.—Through the lumbar region at the level of the fourth lumbar nerve.

1. Posterior nerve-root.
2. Postero-median fissure.
3. Substantia gelatinosa Rolandi.
4. Root-fibres entering gray matter.
5. Central canal.
6. Anterior commissure.
7. Nuclei of origin from which the motor-fibres for muscles of the lower limb arise.
8. Anterior nerve-root.
9. Antero-median fissure.



D.—Through the sacral region at the level of the third sacral nerve. (From a specimen prepared by Dr. A. Bruce.)

1. Postero-median fissure.
2. Posterior nerve-root.
3. Substantia gelatinosa Rolandi.
4. Posterior gray commissure.
5. Anterior commissure.
6. Antero-median fissure.

FIG. 369.—SECTION THROUGH EACH OF THE FOUR REGIONS OF THE CORD. (From specimens prepared by the Weigert-Pal method, therefore the white matter is rendered dark in colour whilst the gray matter is bleached.)

In the lower part of the *conus medullaris* the gray matter in each lateral half of the cord assumes the form of an oval mass joined to its fellow of the opposite side by a thick gray commissure. Here almost the entire bulk of the cord consists

of gray matter, seeing that the white matter is reduced to such an extent that it forms only a thin coating on the outside.

White Matter of the Spinal Cord.—In transverse sections of the cord the three columns into which the white matter is subdivided become very apparent. The **posterior column** is wedge-shaped, and lies between the postero-median fissure and the posterior horn of gray matter. The **lateral column** occupies the concavity of the gray crescent. Behind, it is bounded by the posterior horn of gray matter and the postero-lateral sulcus, whilst in front it extends as far as the outermost fasciculi of the anterior nerve-roots as they pass out from the anterior gray horn. The **anterior column** includes the white matter between the antero-median fissure and the anterior horn of gray matter, and also the white matter which separates the broad extremity of the anterior gray cornu from the surface of the cord. This latter portion of the anterior column is traversed by the emerging fascicles of the anterior nerve-roots.

In cross-sections of the cord the partition of pia mater, which dips in at the posterior paramedian groove and divides the posterior column into the column of Goll and the column of Burdach, is very strongly marked in the cervical regions, but as it is traced downwards into the dorsal region it becomes shorter and fainter, and finally disappears altogether at the level of the eighth dorsal nerve. Below this point there is no visible demarcation of the posterior column into two parts.

The white matter is not present in equal quantity throughout the entire length of the cord. It increases steadily from below upwards, and this increase is most noticeable in the lateral and posterior columns. In the lower part of the conus medullaris the amount of gray matter is actually greater than that of the white matter: but very soon this state of affairs is changed, and in the lumbar region the proportion of gray to white matter is approximately as 1 : 2·1; in the dorsal region as 1 : 5; and in the cervical region as 1 : 5·1. When it is remembered how the gray matter expands in the lumbar and cervical regions, and how greatly it becomes reduced in the dorsal region, the significance of these figures will become more apparent.

Central Canal (canalis centralis).—As previously stated, the central canal is found in the gray commissure. It is a very minute tunnel, barely visible to the naked eye when seen in transverse section, and it traverses the entire length of the cord. Above, it passes into the medulla oblongata, and finally opens into the fourth ventricle of the brain; below, it is continued for a variable distance into the filum terminale, and in this it ends blindly. Only in the lumbar region does the central canal occupy the centre of the cord. Above this level, in the dorsal and cervical regions, it lies very much nearer the anterior than the posterior aspect of the cord; whilst below the lumbar region, as it is traced down into the conus medullaris, it inclines backwards and approaches the posterior aspect of the cord. The calibre of the canal likewise varies somewhat in different parts of the cord. It is narrowest in the dorsal region; and in the lower part of the conus medullaris it expands into a distinct fusiform dilatation (very nearly 1 mm. in transverse diameter), which is termed the **ventriculus terminalis** (Krause).

The central canal is lined by a layer of ciliated columnar cells, the deep tapering ends of which are prolonged into slender processes, which penetrate into the substance of the cord. These cells constitute the lining ependymal cells of the canal. The cilia of the epithelial cells are very early lost, and it is not uncommon to find the canal blocked up by epithelial debris.

The central canal is of interest because it represents in the adult the relatively wide lumen of the early ectodermal neural tube from which the spinal cord is developed.

Filum Terminale.—The delicate thread to which this name is applied is continuous with the lower tapered end of the conus medullaris. It is easily distinguished by its silvery and glistening appearance from the numerous long nerve-roots (cauda equina) amidst which it lies. It is about six inches long, and down to the level of the second sacral vertebra it is inclosed with the surrounding nerve-roots within the theca of dura mater. Piercing the tapered and closed end of the theca at this point, and receiving an investment from it, the filum terminale proceeds downwards in the sacral canal, and finally receives attachment to the periosteum on

the dorsal aspect of the coccyx (Fig. 364, p. 453). It is customary to speak of the filum as consisting of two parts, viz. the filum terminale internum and the filum terminale externum, or the part inside and the part outside the theca of dura mater.

The **filum terminale externum** is simply a fibrous thread, strengthened by the prolongation it receives as it pierces the dura mater. The **filum terminale internum** is largely composed of pia mater; but in its upper half it incloses the terminal part of the central canal, and around this a variable amount of the gray substance of the cord is prolonged downwards into the filum. When transverse sections are made through the upper part of the filum terminale internum some bundles of medullated nerve-fibres are observed clinging to its sides, and with these are associated some nerve-cells identical with those in the spinal ganglia. These represent rudimentary or aborted caudal nerves (Rauber).

Summary of the Chief Characters presented by the Cord in its Different Regions.

Cervical Region.	Dorsal Region.	Lumbar Region.	Sacral Region.
In transverse section, **outline of cord** transversely oval; in the middle of the cervical swelling the transverse diameter being nearly one-third longer than the antero-posterior diameter.	In transverse section, **outline of cord** more nearly circular; but still the transverse diameter is greater than the antero-posterior diameter.	In transverse section, **outline of cord** more nearly circular than in dorsal region.	In transverse section, **outline of cord**, nearly circular, but still somewhat compressed from before backwards.
Postero-median cleft very deep, extending beyond the centre of cord; **antero-median cleft** shallow.	**Postero-median cleft** very deep, extending beyond centre of cord: **antero-median cleft** shallow.	**Postero-median cleft** not nearly so deep as in regions above: **antero-median cleft,** on the other hand, much deeper.	**Postero-median** and **antero-median clefts** of equal depth.
Gray matter greatly increased in quantity in the cervical swelling: anterior horn thick and massive; posterior horn slender in comparison. Lateral horn only evident above the level of the fourth cervical nerve. Formatio reticularis strongly marked.	**Gray matter** greatly reduced in quantity. Both horns slender. Lateral horn well marked. Formatio reticularis scarcely apparent.	**Gray matter** greatly increased in the lumbar swelling. Both horns very thick and massive. Lateral horn absorbed in anterior horn. Formatio reticularis absent.	Both horns of **gray matter** very thick and massive. Lateral horn apparent. No formatio reticularis.
White matter in great quantity, and especially massed in the lateral and posterior columns.	**White matter** less in quantity than in cervical region, but bulking largely in comparison with the quantity of gray matter.	**White matter** small in quantity in relation to higher regions, and very small in amount in relation to increased quantity of gray matter.	**White matter** very small in quantity in comparison with the gray matter.
Posterior paramedian groove and septum well marked.	**Posterior paramedian groove** absent; but the corresponding septum can be traced as low down as the eighth dorsal nerve.	No **posterior paramedian groove** or septum.	No **posterior paramedian groove** and no corresponding septum.
Central canal considerably nearer the anterior surface than the posterior surface of the cord.	**Central canal** considerably nearer the anterior surface than the posterior surface of the cord.	**Central canal** in the centre of the cord.	**Central canal** in the centre of the cord.

Component Parts of the Gray Matter of the Spinal Cord.

Neuroglia enters largely into the constitution of the gray matter of the cord. It forms a bed within which the nervous elements are distributed. These nervous elements consist of (1) nerve-cells and (2) nerve-fibres—both medullated and non-medullated. The nerve-cells lie in small spaces within the neuroglia, whilst the nerve-fibres traverse fine passages the walls of which are formed of the same substance. The neuroglia is thus an all-pervading basis substance, which isolates more or less completely the nervous elements from each other, and at the same time binds them together into a consistent solid mass. In two situations the gray matter presents special characteristics which have earned for it the name of **substantia gelatinosa**, viz. the gray matter which constitutes the immediate surrounding of the central canal, and which is called the **substantia gelatinosa centralis**; and that which forms the apical part of the posterior horn of gray matter, and which receives the name of **substantia gelatinosa Rolandi**. In both situations the substantia gelatinosa stains more deeply with carmine and presents a more translucent appearance; in other respects the substantia centralis and the substantia Rolandi are very different.

The *substantia gelatinosa centralis* forms a thick ring around the central canal, which is traversed by the fine processes which proceed from the deep ends of the ependymal cells which line the canal. It is almost entirely composed of neuroglia.

In transverse sections of the cord the *substantia Rolandi*, in the cervical and dorsal regions, presents the appearance of a V-shaped mass, embracing the extremity of the caput of the posterior horn of gray matter; in the lumbar region this cap assumes a semilunar outline.

In the substantia gelatinosa Rolandi the neuroglia is present in small quantity, and small nerve-cells are developed within it in considerable numbers.

Nerve-Cells.—The nerve-cells are scattered plentifully throughout the gray matter, but perhaps not in such great numbers as might be expected when we note the enormous number of nerve-fibres with which they stand in relation. They are all, without exception, multipolar, and send off from their various aspects several branching protoplasmic processes or dendrites, and one axon, which becomes the axis-cylinder of a nerve-fibre. In size they vary considerably, and it is generally admitted that the bulk of a nerve-cell has a more or less definite relation to the length of the axis-cylinder which proceeds from it.

When the nerve-cells are studied in a series of transverse sections of the cord, it will be noticed that a large proportion of them are grouped in clusters in certain districts of the gray matter; and as these groups are seen in very much the same position in successive sections, it is clear that these cells are arranged in longitudinal columns of greater or less length. Thus we recognise (1) a ventral group or column of cells in the anterior horn of gray matter; (2) an intermedio-lateral group or column in the lateral horn of gray matter, where this exists; and (3) a posterior vesicular column of cells (Clarke's column), forming a most conspicuous group in the mesial part of the cervix of the posterior horn in the dorsal region of the cord.

Other cells besides those forming these columns are scattered somewhat irregularly throughout the gray matter of the posterior horn and the part of the gray crescent which lies between the two horns; and although these also in some measure may be classified into groups, the arrangement thus effected is not of so definite a character as to justify us in dwelling upon it in the present instance.

Ventral Cell-Column and the Origin of the Fibres of the Anterior Nerve-Roots.—The ventral cell-group occupies the anterior horn of gray matter, and in it are found the largest and most conspicuous cells in the spinal cord. It extends from one end of the cord to the other. These ventral nerve-cells have numerous wide-spreading dendritic processes, and it is to be noticed that certain of these dendrites do not confine their ramifications to the gray matter. Thus, some of the cells along the mesial border of the anterior horn of gray matter send dendrites across the mesial plane in the anterior commissure to end in the anterior gray horn of the opposite side; whilst others, lying along the lateral or outer margin of

the anterior horn of gray matter, send dendrites in amongst the nerve-fibres of the adjoining white matter.

The axons or axis-cylinder processes of a large proportion of the ventral cells converge together; and, becoming medullated, form bundles which pass out from the gray matter, and through the white matter which separates the thick end of the anterior horn from the surface of the cord, to finally emerge as the fascicles of the anterior nerve-roots. These cells, then, are the sources from which the nerve-

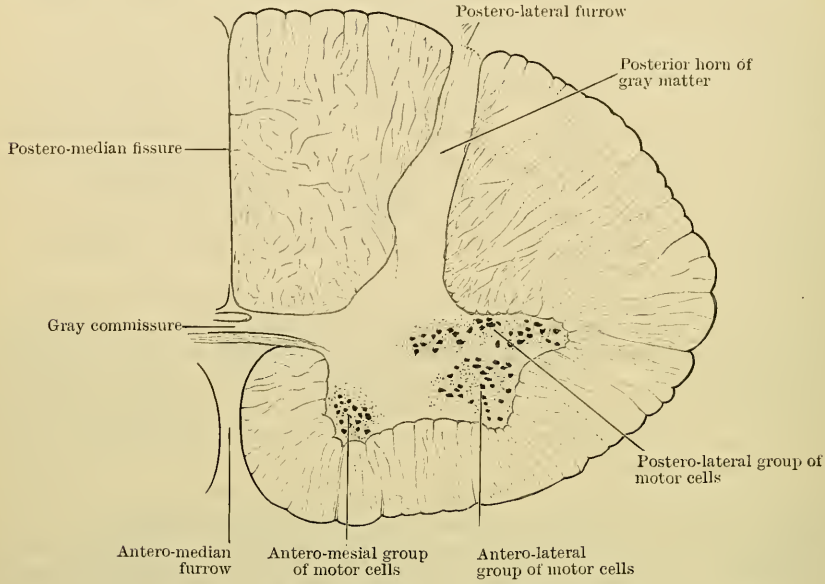


FIG. 370.—SECTION THROUGH THE FIFTH CERVICAL SEGMENT OF THE CORD. (To a large extent founded on Plates in Dr. Bruce's *Atlas*.)

fibres of the anterior nerve-roots proceed, and in consequence they are frequently spoken of as the "motor cells" of the cord. Whilst this is the arrangement of the axons of the great majority of the motor cells, it should be noted that a few cross the mesial plane in the anterior white commissure and emerge in the fascicles of origin of the opposite anterior nerve-root.

The ventral cells are not scattered uniformly throughout the anterior horn of gray matter. They are aggregated more closely together in certain parts of the anterior horn, and thus form sub-groups or columns more or less perfectly marked off from each other.

Thus one sub-group or column of ventral cells occupies the inner or mesial part of the anterior horn of gray matter throughout almost its whole length. In only two segments of the cord is it absent, viz. the fifth lumbar and the first sacral; at this level in the cord alone is its continuity broken (Bruce). It is termed the *ventro-mesial column* or *group* of ventral cells. Behind this cell-column there is another which is classed with it to which the name of *dorso-mesial column* or *group* is given, but this column of cells is not continuous throughout the entire length of the cord. It is present in the dorsal region of the cord where the motor nuclei for the muscles of the limbs are absent, and it is also seen in two or three of the segments of the cervical region and in the first lumbar segment (Bruce); elsewhere it is not represented.

In the cervical and lumbar swellings of the cord, where the marked lateral outgrowth is added to the outer side of the anterior horn of gray matter, certain groups of large multipolar cells are visible. These are the nuclei of origin of the motor-fibres which supply the muscles of the limbs, and consequently they are not represented in the upper three cervical segments of the cord; nor in any of the dorsal segments, with the exception of the first dorsal segment; nor in the two lowest sacral segments.

These *lateral cells* are arranged in several columns, which extend for varying distances in the superadded lateral parts of the anterior horn of gray matter. The two main columns are a *ventro-lateral* and a *dorso-lateral column*; in certain segments there is likewise a *post-dorso-lateral column*, and in a number of segments in the lumbar and sacral regions a *central column* of cells (Bruce).

There cannot be a doubt that the grouping of the motor cells in the anterior horn of gray matter of the cord stands in relation to the muscle groups to which their axis-cylinder processes are distributed; but from what has been said it will be apparent that sharply defined cell-clusters associated with particular muscles do not exist. Still, much can be learned regarding the localisation of the motor nuclei in the anterior horn of gray matter of the cord from the study of the changes which occur in the cell-columns after atrophies of isolated muscles or groups of muscles, and after complete or partial amputations of limbs. It has been pointed out that the long muscles of the trunk (as, for example, the different parts of the erector spinae muscle) receive nerve-fibres from all the segments of the cord. Now, we have noted that there is only one cell-column, the ventro-mesial column, which pursues an almost uninterrupted course throughout the entire length of the cord. It may be assumed, therefore, that the nerve-fibres which go to these long trunk-muscles take origin in these mesial cells.

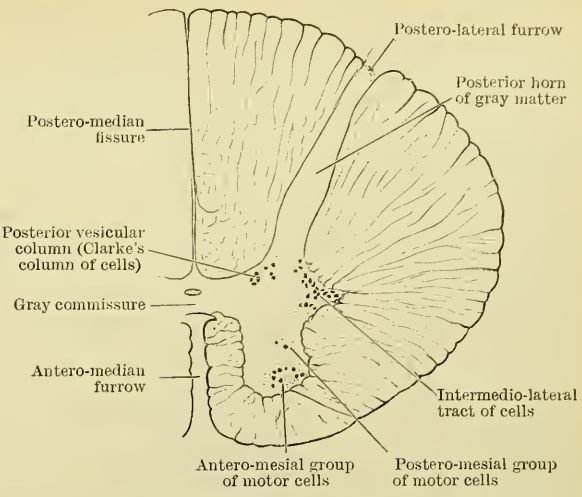


FIG. 371.—SECTION THROUGH THE EIGHTH DORSAL SEGMENT OF THE SPINAL CORD. (To a large extent founded on Plates in Dr. Bruce's *Atlas*.)

Edinger states that in the anterior horn of gray matter the nuclei of origin of the nerves which supply the proximal muscles are medially placed; that those for the distal muscles are in general situated laterally. If this be the case, the cells connected with the shoulder muscles would lie nearer the middle of the anterior horn of gray matter than those which are connected with the hand-muscles. In cases where the forearm and hand, or the leg and the foot, are amputated, it would appear that it is the postero-lateral column of cells that shows changes in consequence of its separation from the muscles to which its fibres are distributed.[1]

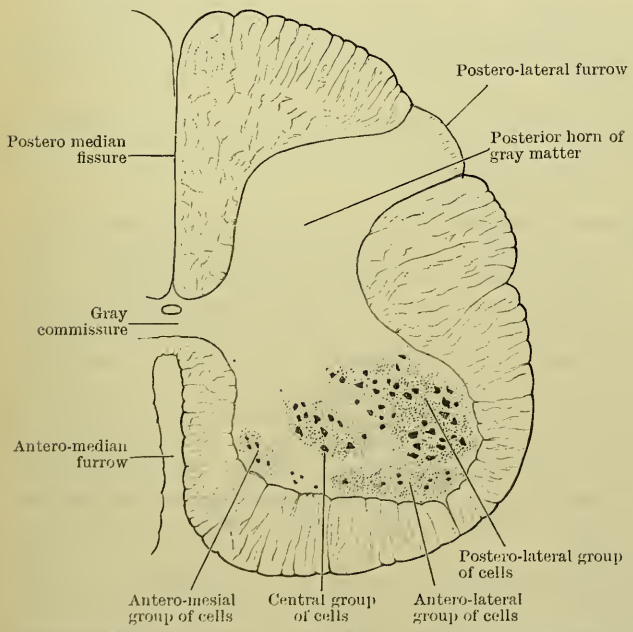


FIG. 372.—SECTION THROUGH THE THIRD LUMBAR SEGMENT OF THE SPINAL CORD TO SHOW THE GROUPING OF THE MOTOR CELLS. (To a large extent founded on Plates in Dr. Bruce's *Atlas*.)

Intermedio-lateral Cell-column.—The intermedio-lateral cells form a long slender column which extends throughout the entire dorsal region of the cord in the lateral horn of gray matter. It is also prolonged downwards into the first and second lumbar segments, where it disappears. In

[1] Those who seek further information regarding the grouping of the ventral cells of the cord, may with advantage study Dr. Alexander Bruce's *Atlas of the Spinal Cord*.

transverse sections through the cord this cell-group presents a very characteristic appearance, because the cells which compose it are small and are closely packed together. Although these cells, as a continuous column, are restricted to the region indicated, it should be noted that the same group of cells reappears above in certain of the cervical segments and also in the third and fourth sacral segments. The function and connexions of these cells are unknown. It has been suggested that they give origin to vaso-motor, pilo-motor, and sweat-gland nerves, and have a very close connexion with the sympathetic nervous system.

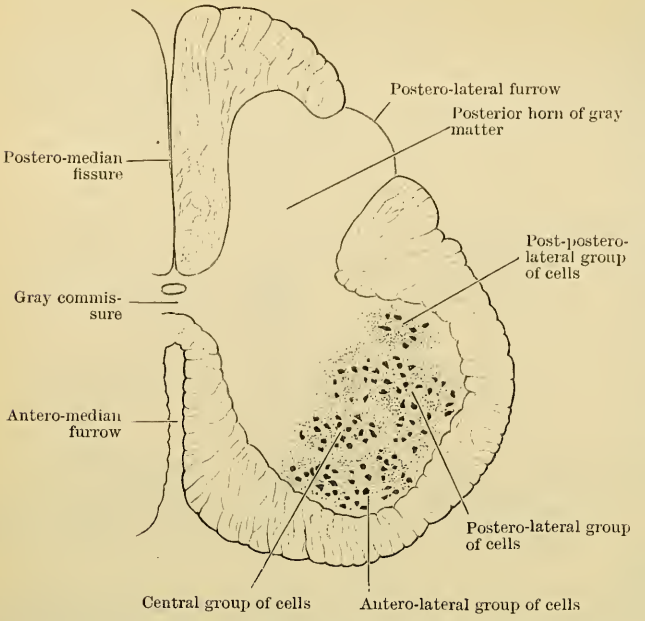


FIG. 373.—SECTION THROUGH THE FIRST SACRAL SEGMENT OF THE SPINAL CORD TO SHOW THE GROUPING OF THE MOTOR NERVE-CELLS. (To a large extent founded on Plates in Dr. Bruce's *Atlas*.)

In a recent research by Bruce the following important points in regard to the intermedio-lateral cell-column have been determined.

It is not quite continuous. In the eighth cervical, first dorsal, and also in a part of the second dorsal segment, as well as in the first and second lumbar segments, the cells are in separate clusters. Throughout the rest of the dorsal region it forms a moniliform chain of cells, situated partly in the lateral horn and partly in the gray matter behind it. Some outlying cells are situated in the white matter in the neighbourhood of the lateral horn.

The limits of the tract are from lower two-thirds of eighth cervical to the lower end of the second lumbar or perhaps the upper end of the third lumbar segment. It is found also in the first, second, and third cervical, and in the third and fourth sacral segments. It reaches its maximum size in the third and fourth dorsal segments.

Posterior Vesicular Column—Clarke's Column.—This occupies the posterior horn of gray matter and is the most conspicuous of all the cell-groups in the cord. It does not, however, extend along the whole length of the cord; indeed it is almost entirely confined to the dorsal region, and in consequence it is sometimes referred to as the "dorsal nucleus." Above, it begins opposite the seventh or eighth cervical nerve, whilst below, it may be traced to the level of the second lumbar nerve, where it disappears. In transverse section of the cord it presents an oval outline, and is seen in the inner part of the cervix of the posterior horn of gray matter immediately behind the gray commissure (Fig. 369 B, p. 458). On the outer side it is circumscribed by numerous curved fibres from the entering posterior nerve-root, and in the lower dorsal region of the cord (opposite the eleventh and twelfth dorsal nerves) it becomes so marked that it forms a bulging on the inner aspect of the posterior gray horn.

The cells of Clarke's column are large, and possess several dendritic processes. The axons enter the lateral column of white matter and there form a strand of fibres, which will later on be described under the name of the **direct cerebellar tract.**

In addition to the topographical subdivision of the nerve-cells of the cord indicated above, it is now usual to classify them according to the nature of the axons which proceed from them. Thus we have (1) the cells of Golgi or cells with short axons, and (2) cells with long axons.

The **cells of Golgi** possess axons which do not emerge from the gray matter, but bring neighbouring cells into touch with each other. The **cells with long axons** are of two kinds, viz. radicular cells and strand-cells.

The **radicular cells** are those from which the axon emerges from the cord in the shape of an efferent nerve-fibre. Thus the "motor cells" which supply the axis-cylinder processes of the

anterior nerve-roots belong to this class. The **strand-cells** are those which contribute their axons to the formation of those fibres which form certain of the strands or tracts which are found in the white matter of the cord.

Nerve-fibres in the Gray Matter of the Cord.—Nerve-fibres both of the medullated and non-medullated variety pervade every part of the gray matter. They are of three kinds, viz. (1) collaterals, (2) terminations of nerve-fibres, (3) axons given off by the cells. Many of the nerve-fibres which compose the columns of white matter of the cord give off numerous fine collateral branches, which pass into the gray matter from all sides and finally end in relation with the nerve-cells. The majority of the nerve-fibres themselves, which thus give off collaterals, finally enter the gray matter, and end similarly. As already noted, the axons of the cells of Golgi remain within the gray matter, but the others emerge either for the purpose of entering a peripheral nerve or for the purpose of entering a strand of fibres in the white matter of the cord.

The nerve-fibres thus derived are interwoven together in the gray matter of the cord in a dense inextricable interlacement.

Component Parts of the White Matter of the Cord.

The white matter of the cord is composed of medullated nerve-fibres embedded in neuroglia. The fibres, for the most part, pursue a longitudinal course; and from the deep surface of the pia mater which surrounds the cord fibrous septa or partitions are carried in along vertical planes between the fibres, so as to form an irregular and very imperfect fibrous framework of support. The neuroglia is disposed in a layer of varying thickness around the cord, subjacent to the pia mater, and is carried into the cord so as to give a coating to both sides of the various pial septa. The neuroglia also is disposed around the various nerve-fibres, so that each of these may be said to lie in a canal or tunnel of this substance. The nerve-fibres are all medullated, but they are not provided with primitive sheaths. It is the medullary substance of the nerve-fibres which gives to the white matter its opaque, milky-white appearance. When a thin transverse section of the cord is stained in carmine and examined under the microscope the white matter presents the appearance of a series of closely-applied circles, each with a dot in the centre. The dot is the transversely divided axis-cylinder of a nerve-fibre, and the dark ring which forms the circumference of the circle represents the wall of the neuroglial canal which is occupied by the fibre. The medullary substance is very faintly seen. It presents a filmy or cloudy appearance between the axis-cylinder and the neuroglial ring.

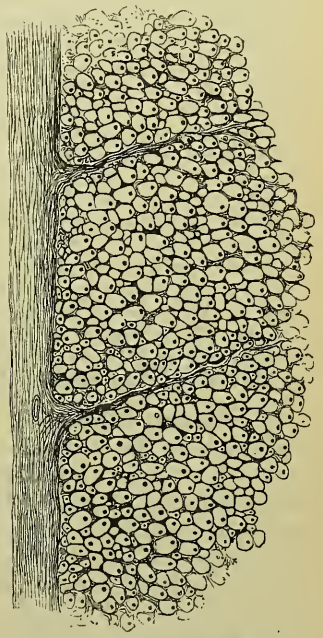


Fig. 374.—Transverse Section through the White Matter of the Cord, as seen through the microscope.

Arrangement of the Nerve-fibres of the White Matter in Strands or Tracts.—When the white matter of a healthy adult cord is examined the fibres which compose it are seen to vary considerably in point of size; and although there are special places where large fibres—or it may be small fibres—are present in greater numbers than elsewhere, yet as a rule both great and small fibres are mixed up together. Absolutely no evidence can be obtained in such a cord, by any means at our disposal, of the fact that the longitudinally arranged fibres are grouped together in more or less definite tracts or strands, the fibres of which run a definite course and present definite connexions. Yet we know this to be the case, and the existence of these separate tracts has been proved both by physiological and by embryological investigation.

The **physiological evidence** depends on the fact that when a nerve-fibre is severed the part which is detached from the nerve-cell from which it is an offshoot degenerates, whilst the part which remains connected with the nerve-cell undergoes little or no change. This is called the law of "Wallerian" degeneration. Thus, if in a living animal one-half of the cord be cut across, and after a few weeks the animal be killed and the cord examined, it will be seen that there are degenerated tracts of fibres in the white matter, both above and below the plane of division; but, still further, it will also be manifest that the tracts which are degenerated above the plane of division are not the same as those which are degenerated in the part of the cord which lies below this level. The interpretation of this is obvious. The nerve-tracts which have degenerated above the plane of section are the offshoots of nerve-cells which lie in lower segments of the cord or in spinal ganglia below the plane of section. Severed from these nerve-cells, they undergo what is called ascending degeneration. The nerve-tracts, on the other hand, which have degenerated in the portion of the cord below the plane of division are the axons of cells which lie at a higher level than the plane of section, either in higher segments of the cord or in the brain itself. Cut off from the nerve-cells from which they proceed, they present an example of descending degeneration.

The **embryological evidence** we owe to Flechsig, and it is no less satisfactory. It depends upon the fact that nerve-fibres in the earliest stages of their development consist of naked axis-cylinders, and are not provided with medullary sheaths. Further, the nerve-fibres of different strands assume the medullary sheaths at different periods. By examining the fœtal cord at different stages of its development, it is a comparatively easy matter to locate the different tracts of fibres by evidence of this kind. Speaking broadly, the tracts which myelinate first are those which bring the cord into relation with the peripheral parts (skin, muscles, etc.); then those fibres which bind the various segments of the cord together; next, those which connect the cord with the cerebellum; and, lastly, the tracts which connect the cord with the cerebrum. The nervous apparatus for the performance of automatic movements is fully provided, therefore, before this is put under the control and direction of the higher centres. It by no means follows that in all the higher animals corresponding strands myelinate at relatively corresponding periods. Take the case of a young animal which from the time of its birth is able to move about and perform voluntary movements of various kinds in a more or less perfect manner, and compare it with the helpless new-born human infant which is only capable of exhibiting automatic movements. In the former the pyramidal tracts, or motor tracts, which descend from the cerebrum into the cord, and which are the paths along which the mandates of the will travel, myelinate at an early period; whilst in the human infant the corresponding fibres do not obtain their medullary sheaths until after birth. The study of the dates, therefore, at which the various strands of nerve-fibres myelinate not only gives the anatomist a means of locating their position in the white matter of the cord, but it also affords the physiologist most important information regarding their functions, and also the periods at which these functions are called into play.

It is a matter of interest to note that influences which either accelerate or retard the periods at which nerve fibres are brought into functional activity have also an effect in determining the dates at which these fibres assume their sheaths of myelin. Thus, when a child is prematurely born the whole process of myelinisation is, as it were, hurried up; and further, when in new born animals light is freely admitted to one eye whilst it is carefully excluded from the other, the fibres of the optic nerve of the former myelinate more rapidly than those of the opposite nerve.

Posterior Column of the Cord and the Posterior Roots of the Spinal Nerves.—In the cervical and upper dorsal regions of the cord the posterior column is divided by the posterior paramedian septum into the **tract of Burdach**, which lies externally and next the posterior horn of gray matter, and the **tract of Goll**, which lies internally and next the postero-median septum. The tract of Burdach is composed of nerve-fibres, which are for the most part larger than those entering into the formation of Goll's tract, and both tracts have a most intimate relation to the posterior nerve-roots; indeed, they are both almost entirely composed of fibres which enter the cord by these roots and then pursue a longitudinal course.

The nerve-fibres which form the posterior nerve-roots, on entering the cord along the postero-lateral groove, divide within the tract of Burdach into ascending and descending branches. These branches diverge abruptly from each other; and the former take an upward course, whilst the latter proceed downwards. The **descending fibres** are as a rule short, and soon end in the gray matter of the cord. These descending fibres occupy an area in the posterior column near to the place of entrance of the nerve-root. This area, when the spinal cord is divided, undergoes descending degeneration and then presents a comma-shaped outline. The fibres in question are included under the name of the **comma tract of Schultze.**

The **ascending fibres** vary greatly in length, and at varying distances from the point where the parent fibres enter the cord they end in the gray matter. A small contribution of ascending fibres, however, from each posterior nerve-root, extends upwards to the upper end of the cord, to end in the medulla oblongata.

As each posterior nerve-root enters, its fibres range themselves in the outer part of

the tract of Burdach close up against the posterior horn of gray matter. The nerve-

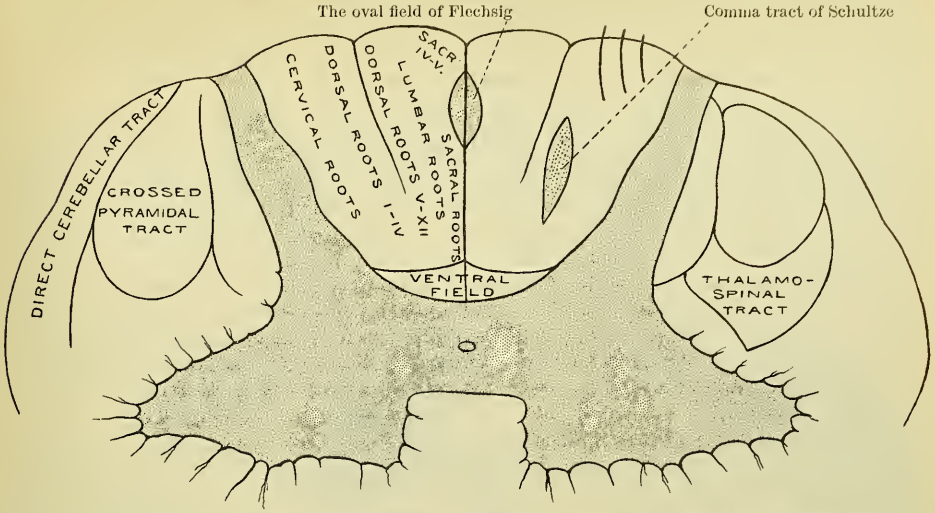


FIG. 375.—DIAGRAM TO SHOW THE ARRANGEMENT OF THE FIBRES OF THE POSTERIOR NERVE-ROOTS IN THE POSTERIOR COLUMNS OF THE CORD. The oval field of Flechsig is present in the lumbar region and is composed of fibres which degenerate in a downward direction, and which are not derived from the posterior nerve-roots. In all probability they are commissural fibres (from Edinger, modified).

fibres of the nerve-root next above take the same position, and consequently those which entered from the nerve immediately below are displaced inwards, and come to lie in the tract of Burdach nearer to the mesial plane. This process goes on as each nerve-root enters, and the result is that the fibres of the lower nerves are gradually pushed nearer and nearer to the postero-median septum in a successive series of lamellar tracts. Of course the greater proportion of the fibres, which are thus carried upwards from the posterior nerve-roots, sooner or later leave the posterior column and enter the gray matter, to end there in relation to some of its cells; but, as we have said, every posterior nerve-root sends a few fibres up the whole length of that portion of the cord which lies above, and thus the posterior column gradually increases in bulk as it is traced upwards, and in the upper reaches of the cord a tract of Goll becomes evident. This tract of Goll is composed of the long ascending fibres of the posterior nerve-roots, which have entered the lower segments of the cord. To put the matter differently, the fibres of the sacral roots are displaced inwards by the entering lumbar fibres, while the fibres of the lumbar roots are in their turn pushed inwards by the entering dorsal fibres, and, lastly, the fibres of the cervical roots displace the dorsal fibres. The difference between the tract of Goll and the tract of Burdach simply consists in this, that the former is composed of the fibres of posterior nerve-roots which have entered the cord at a lower level than those which enter into the formation of the column of Burdach. The fibres of Goll's tract, taking them as a whole, must therefore necessarily run a very much longer course.

Our knowledge of the constitution of the posterior columns of the cord is largely derived from studying the course of degeneration in monkeys, in which the cord has been cut across—either partially or completely. It would appear, from the examination of the human cord which has been injured or compressed, that the lamination of the fibres entering from the series of posterior nerve-roots is not nearly so complete as in the case of the monkey.

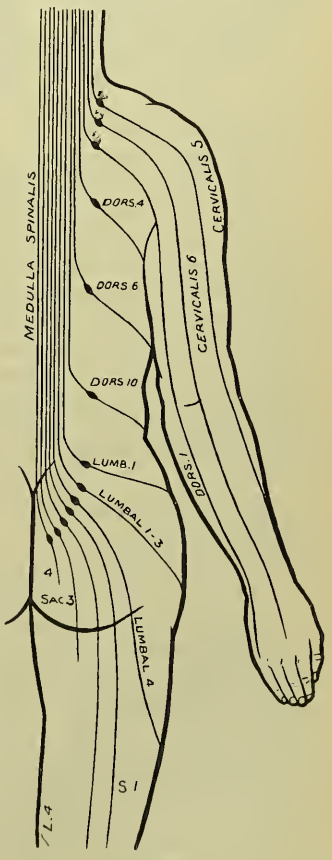


FIG. 376.—DIAGRAM TO SHOW THE MANNER IN WHICH THE FIBRES OF THE POSTERIOR NERVE-ROOTS ENTER AND ASCEND IN THE POSTERIOR COLUMN OF THE CORD (from Edinger).

Numerous collateral fibrils stream into the gray matter of the posterior horn both from the ascending and descending branches of the entering fibres of the posterior nerve-roots. These are classified into long and short collaterals. The **long collaterals** extend forward into the anterior horn of gray matter and end in relation to the ventral nerve-cells. The **short collaterals** end in relation to the nerve-cells in the substantia Rolandi, and other nerve-cells of the posterior horn of gray matter.

The majority of the fibres of the posterior nerve-root enter the cord on the inner side of the apex of the posterior horn of gray matter. The manner in which these are related to the columns of Burdach and Goll has been noticed; but a certain number of those fibres which lie most externally take a curved course forwards on the inner side of the posterior horn of gray matter and then pass into it. In the dorsal region these curved fibres end in connexion with the cells of Clarke's column (Fig. 369, p. 458).

Tract of Lissauer.—This is a small tract of nerve-fibres of minute calibre which assume their medullary sheaths at a comparatively late period. It is placed at the surface of the cord close to the postero-lateral furrow. It is formed by some of the outer fibres of the posterior nerve-roots, which do not enter the tract of Burdach, and which pass upwards in the cord close to the substantia gelatinosa Rolandi, in which they ultimately end.

It must now be evident that the fibres which enter the cord through each posterior nerve-root have three main modes of distribution: (1) the majority take part in the formation of the columns of Burdach and Goll; (2) a few lie close to the posterior horn of gray matter and describe a series of graceful curves as they pass forwards prior to turning outwards into the gray matter, to end, in the dorsal region, in Clarke's vesicular column; (3) a third series form Lissauer's tract and end in connexion with the cells of the substantia gelatinosa Rolandi and other cells in the posterior and anterior horns of gray matter.

The fibres derived from the posterior nerve-roots which ascend in the posterior columns of the cord to the medulla oblongata of the brain constitute a direct sensory tract; other fibres are described which give rise to a crossed sensory tract termed the **spino-thalamic tract.** These latter fibres arise as the axons of certain of the cells in the posterior horn in connexion with which fibres from the posterior nerve-roots have ended, and crossing to the opposite side of the cord through the anterior commissure they ascend in the anterolateral column to the brain, where they ultimately reach the optic thalamus. As the spino-thalamic tract ascends in the cord its fibres are not gathered into a compact strand, but are more or less loosely scattered in the lateral column.

Association Fibres in the Posterior Column.—But the whole of the fibres of the posterior column are not derived from the posterior nerve-roots. A few fibres exist in this column which have a different origin. They are derived from certain of the cells of the gray matter of the cord, and entering the posterior column divide into ascending and descending branches which pass upwards and downwards in the column for a varying distance before they finally turn in to end in the gray matter at a higher and a lower level. These fibres, therefore, constitute links of connexion between different cord segments, and thus they are termed **association** or **longitudinal commissural fibres.** Our information regarding these fibres at present is somewhat defective; but it is believed that the deepest part of the column, *i.e.* the part next the posterior gray commissure and termed the **ventral field,** and also the **descending septo-marginal tract** of Bruce, placed in apposition with the postero-median septum and in the adjoining part of the surface, belong mainly to this category.

Lateral Column of the Cord.—In the lateral column of the cord the well-established tracts are:—

1. The direct cerebellar tract.
2. The tract of Gowers.
3. The crossed pyramidal tract.

The remainder of the column goes under the name of the **lateral basis-bundle.**

The **direct cerebellar tract** (fasciculus cerebello-spinalis) is a band-like strand which lies in relation to the surface of the cord immediately in front of the postero-lateral groove. It is an ascending tract, and is composed for the most part of coarse, large nerve-fibres, which are derived from the nerve-cells of the posterior vesicular column (Clarke's column) in the posterior horn of gray matter. It is, therefore, not found throughout the whole length of the cord. It first appears in the lower part of the dorsal region; and as it ascends it gradually increases in size as it is joined by the axons of the cells of Clarke's column, which lie at higher levels. It finally enters the medulla oblongata, and through this proceeds to the cerebellum, in which it ends.

It must not be forgotten that each posterior nerve-root in the dorsal region of the cord gives a contribution of fibres to the posterior vesicular column of cells from which the fibres of the direct cerebellar tract arise (see p. 468). In this way a connexion is established between the posterior roots of the dorsal nerves and the cortex of the cerebellum. It is believed that the direct cerebellar tract is an important factor in bringing about a proper co-ordination of muscular movements.

Gowers's tract (fasciculus antero-lateralis superficialis) lies in front of the direct cerebellar tract, and, like it, next the surface of the lateral column. It is also an ascending tract, and it likewise (in part at least) ultimately reaches the cerebellum, although after leaving the cord it takes a different route to gain its destination. In transverse sections of the cord it presents a comma-shaped appearance, the thick part abutting against the direct cerebellar tract, and the narrower portion tapering forwards into the region of the emerging anterior nerve-roots. The tract of Gowers begins at a lower level in the cord than the direct cerebellar tract and it increases in volume as it is traced upwards. The fibres of this tract have probably their origin in the cells of the posterior horn of gray matter, but on this point there is at present no precise information.

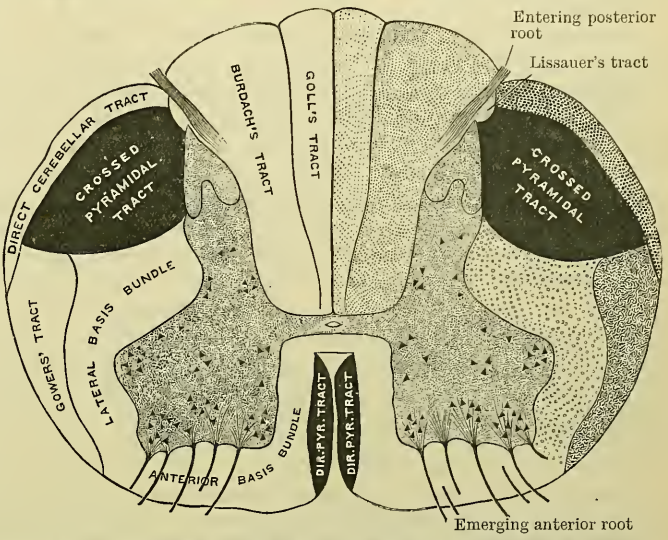


Fig. 377.—Diagrammatic Representation of a Transverse Section through the Spinal Cord.

The nerve tracts in the white matter and the clusters of nerve-cells in the gray matter are shown.

The **crossed pyramidal tract** (fasciculus cerebro-spinalis lateralis) is a large well-defined descending tract, which lies immediately in front of the posterior horn of gray matter and subjacent to the direct cerebellar tract, which shuts it out from the surface of the cord. Below the point where the direct cerebellar tract begins the crossed pyramidal tract becomes superficial, and in this position it can be traced as low as the fourth sacral nerve, at which level it ceases to exist as a distinct strand. The crossed pyramidal tract is composed of an admixture of both large and small fibres. These arise in the brain from the large pyramidal cells of the motor or Rolandic area of the cerebral cortex, and pass downwards through various subdivisions of the brain to gain the spinal cord. As they enter the cord they cross the mesial plane from one side to the other, and it thus happens that the crossed pyramidal tract in the right lateral column of the cord has its origin in the cortex of the left cerebral hemisphere, and *vice versa*. As the tract descends in the cord it gradually diminishes in size; and this is due to the fact that, as it traverses each spinal segment, numerous fibres leave it to enter the anterior horn of gray matter, and end in connexion with the ventral motor cells from which the fibres of the anterior nerve-roots arise. The entire strand is ultimately exhausted in this way. Numerous collateral fibrils spring from the pyramidal fibres, and, entering the gray matter, end in a similar manner, and in this way a single pyramidal fibre may be connected with several spinal segments before it finally ends. The crossed pyramidal tract must be regarded as a great motor strand which brings the spinal motor apparatus under the control of the will.

Schäfer believes that many of the pyramidal fibres end in connexion with the cells of Clarke's column.

In the rat, mouse, guinea-pig, squirrel, sheep, kangaroo, etc., the pyramidal tract lies in the posterior column of the cord.

The **lateral basis-bundle** (fasciculus lateralis proprius) represents the remainder of the lateral column. Our information regarding it is still imperfect; but it would appear that its fibres are largely derived from the cells situated in all parts of the gray matter, and also from the nerve-cells of the opposite side of the cord. After a course of very varying length in the basis-bundle, these fibres turn inwards and re-enter the gray matter. Such fibres may thus be regarded as **inter-segmental association fibres** binding two or more segments of the cord together. It may be mentioned that the association fibres which link together segments of the cord which are near to each other lie close to the gray matter, whilst those which connect the more distant segments are situated further out in the lateral basis-bundle.

Anterior Column of the Cord.—One well-defined tract is situated in the anterior column. This is termed the direct pyramidal tract. The remainder of the column receives the name of the anterior basis-bundle.

The **direct pyramidal tract** (fasciculus cerebro-spinalis anterior) is usually a nerve-strand of small size which lies next the antero-median fissure. As a rule, it cannot be traced lower than the middle of the dorsal region of the cord. It is a descending tract and must be associated with the crossed pyramidal tract of the opposite side, seeing that both of these strands arise from the motor area of the cortex of the same cerebral hemisphere. From this, it must be clear that the direct pyramidal tract does not cross the mesial plane as it enters the cord, but descends on the side of the cord corresponding to the cerebral hemisphere in which it arises. All the same its fibres do not end in the same side of the cord, but at every step along the path of the strand they make use of the anterior commissure and cross to the opposite side of the cord, to terminate in relation to the opposite ventral motor cells in the same manner as the crossed pyramidal fibres.

From this crossing of the pyramidal tracts, it results that the destruction of the fibres which compose them as they descend in one side of the brain must result in paralysis of the muscles supplied by the efferent nerves of the opposite side of the cord.

In cases of old brain lesion it is sometimes possible to detect some degenerated fibres in the crossed pyramidal tract of the sound side of the spinal cord, and from this it is supposed that this tract contains a few uncrossed fibres. If this be the case, each side of the cord stands in connexion with the motor area of both cerebral hemispheres.

It is well to note that the fibres of both pyramidal tracts are not medullated until the time of birth. They are the latest of all the cord-tracts to myelinate.

The **anterior basis-bundle** (fasciculus anterior proprius), like the lateral basis-bundle, is composed largely of fibres which arise from the cells of the gray matter of the cord, and act the part of **intersegmental association fibres.**

Summary of the Constitution of the White Matter of the Cord.—The white columns of the cord are formed of two kinds of nerve-fibres :—

1. Those which enter the cord from without.
2. Those which take their origin from the cells within the gray matter of the cord itself.

Under the first category we include (*a*) the greater part of the fibres of the posterior column (columns of Burdach and Goll), which arise from the cells of the spinal ganglia, and which enter the cord as the posterior nerve-roots; and (*b*) the crossed and direct pyramidal tracts which come from the motor cells of the cerebral cortex.

The fibres which arise within the gray matter of the cord may be classified thus: (*a*) Fibres which pass out from the cord as efferent nerves (anterior nerve-roots); (*b*) fibres which form long tracts and pass up the cord to enter the brain (direct cerebellar tract and the tract of Gowers); (*c*) fibres which form short tracts, linking together different segments of the cord (intersegmental association fibres in each of the three columns of the cord).

Anterior White Commissure.—The anterior commissure is composed of medullated nerve-fibres passing from one side of the cord to the other and entering the anterior horn of gray matter, and also the anterior column of white matter. It is to be regarded more as a decussation than as a commissure, and its width, which

varies somewhat in different regions, fluctuates in correspondence with the diameter of the cord.

Amongst the fibres which cross in the anterior commissure may be mentioned: (1) The fibres of the direct pyramidal tract; (2) collaterals from both the ventral and lateral columns; (3) axons of many of the cells of the gray matter; (4) the dendritic processes of some of the mesial ventral cells.

Posterior Gray Commissure.—Although this is composed of gray matter with a large admixture of neuroglia, numerous transverse nerve-fibres pass through it, so as to bind the cells of one side of the cord to those of the other.

Development of the Spinal Cord.

In the chapter upon General Embryology it has been pointed out (p. 21) that the brain and cord first take shape in the form of a tube of ectoderm, which receives the name of the **neural tube.** Three expansions, placed one behind the other at the cephalic end of the tube, represent the early brain; whilst behind these primitive cerebral vesicles comes the elongated narrower part of the tube, which at this stage represents the spinal cord. By a developmental process, which we now have to study, the walls of this portion of the neural canal give rise to the various elements which build up the substance of the cord, whilst a portion, if not the whole, of the primitive cavity is preserved as the central canal of the cord. The account which is here given of the development of the cord is taken almost entirely from the writings of Professor His.

When first formed, the neural tube is compressed from side to side and presents an oval outline in transverse section (Fig. 16, p. 21). The two lateral walls are very thick, whilst the narrow dorsal and ventral portions of the wall are thin, and are termed the **mid-dorsal** and **mid-ventral laminæ** (Fig. 378). The cavity of the tube in transverse section appears as a narrow slit. At this stage the wall of the neural tube is formed of a series of elongated neuro-epithelial columnar cells, closely applied to each other and extending throughout the whole thickness of the wall. The inner ends of these long columnar cells unite to form a delicate membrane termed the **internal limiting membrane,** which lines the lumen of the tube, whilst their outer ends present a similar relation to an **external limiting membrane,** which invests the outer surface of the tube. The name of **spongioblasts** is given to these cells, and they soon develop in such a manner as to form the sustentacular framework of the growing cord. Between their inner parts, immediately subjacent to the internal limiting membrane, a series of clefts or open spaces are formed, in which appear large numbers of round cells called **germinal cells.** The precise origin of these germinal cells is not at present satisfactorily established; but they rapidly increase in number, and in the human embryo of four weeks they are seen to form an almost continuous layer beneath the internal limiting membrane. It is well to note, however, that in the thin mid-dorsal and mid-ventral laminæ no germinal cells are formed. Here the wall remains purely spongioblastic. The peripheral portions of the spongioblasts likewise undergo a marked transformation. They give off branches or processes, and by the interlacement of these a sponge-like network with irregular meshes is formed in the outer portion of the wall of the neural tube. The

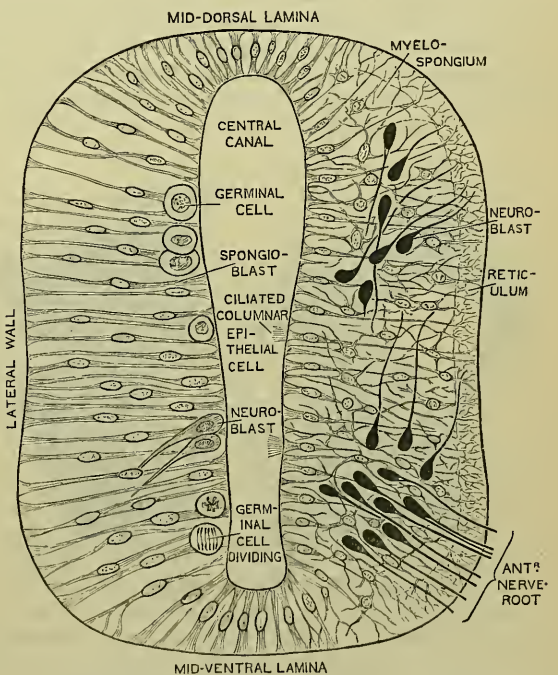


Fig. 378.—Schema of a Transverse Section through the Early Neural Tube (Young).

The left side of the section shows an earlier stage than the right side.

entire sustentacular framework into which the spongioblasts are developed is termed the **myelosponge**.

The numerous germinal cells which are placed in the clefts between the inner columnar portion of the myelosponge are the progenitors of the nerve-cells. Many of them show karyokinetic stages, and by their division they give rise to the **neuroblasts** or young nerve-cells. A neuroblast presents a very characteristic pear-shaped appearance. From the body of the cell a tapering process grows out, and this represents the early axis-cylinder process or axon of the cell. But the crowds of neuroblasts which are thus formed do not remain in their early primitive position beneath the internal limiting membrane. They migrate outwards, and in the course of time they come to lie in the part of the myelosponge immediately adjoining the reticular meshwork, which is formed by the outer parts of the spongioblasts. Here their further outward migration is arrested. The reticular meshwork would almost appear to act as a sieve or a filter, which prevents their progress towards the periphery of the wall of the tube. It offers no impediment to the actively growing axons of the neuroblasts, however, which freely enter it and thread their way through it. At this stage the thick lateral wall of the neural tube presents three layers, viz. :—

1. An inner layer, formed by the columnar part of the myelosponge forsaken by the neuroblasts. This is termed the **ependymal layer**, and it ultimately resolves itself into the layer of columnar ciliated epithelial cells which lines the central canal of the cord.

2. An intermediate layer, in which the neuroblasts are present, and which is afterwards converted into the gray matter of the cord. This is called the **mantle layer**.

3. An outer layer, formed of the sponge-like meshwork of the outer parts of the original spongioblasts. Into this the axons of many of the neuroblasts are seen threading their way. This layer is ultimately transformed into the white matter of the cord, and at this stage it may be termed the **peripheral reticular layer**.

Alar and Basal Laminæ of the Lateral Wall of the Neural Tube.—From what has been said, it must be evident that the changes detailed above are confined to the thick lateral walls of the neural tube. In these alone do neuroblastic cells arise, whilst the thin mid-dorsal and mid-ventral laminæ remain spongioblastic throughout. But whilst these changes are going on, the thick lateral wall begins to bulge outwards in an angular fashion, so as to widen the central cavity of the tube and become itself, along the line where the cavity is widest, demarcated into two portions—a narrow dorsal strip termed the **alar lamina**, and a broader ventral strip called the **basal lamina**. The cavity

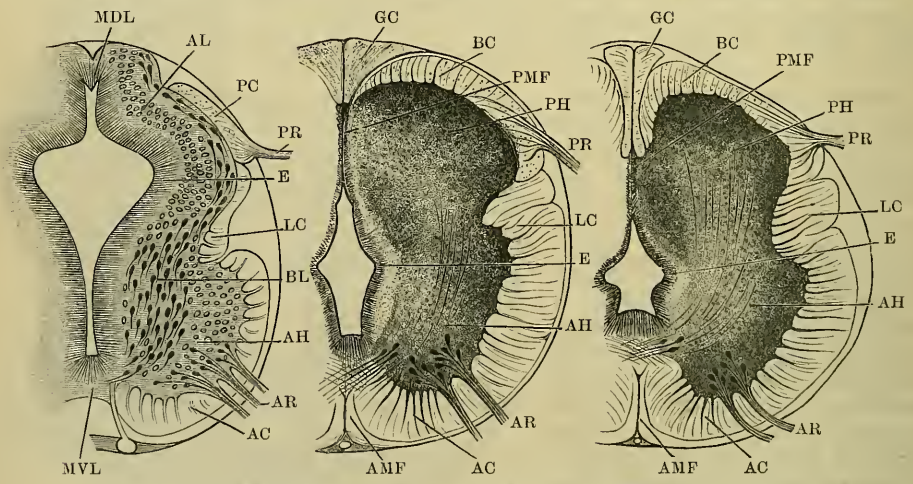


FIG. 379.—THREE STAGES IN THE DEVELOPMENT OF THE SPINAL CORD (His).

AC.	Anterior column.	BC.	Column of Burdach.	MVL.	Mid-ventral lamina.
AH.	Anterior horn of gray matter.	BL.	Basal lamina.	PC.	Early posterior column.
AL.	Alar lamina.	E.	Ependyma.	PH.	Posterior horn of gray matter.
AMF.	Antero-median fissure.	GC.	Column of Goll.	PMF.	Postero-median fissure.
AR.	Anterior nerve-root.	LC.	Lateral column.	PR.	Posterior nerve-root.
		MDL.	Mid-dorsal lamina.		

of the tube now appears on transverse section more or less lozenge-shaped, and it is at the lateral angles of the lozenge that this subdivision of the lateral wall becomes evident.

This subdivision is a fundamental one, being present in the brain-part as well as the

cord-part of the neural tube. By it the thick lateral wall is resolved into two longitudinal strips (the alar and basal laminæ), which extend along the whole length of the tube, and which present definite and precise relations with the entering and emerging roots of the various cranial and spinal nerves. Confining our attention to the spinal cord, the posterior nerve-root is seen to enter the alar lamina, whilst the anterior nerve-root takes origin within and emerges from the basal lamina.

Further Development of the Gray and White Matter of the Cord.—In the ventral part of the basal lamina the mantle layer thickens into a mass, which is readily recognised as the rudiment of the anterior horn of gray matter, and in this neuroblastic cells congregate in much larger numbers than elsewhere. Further, these neuroblastic cells begin to arrange themselves into groups, and the axis-cylinder processes of a large proportion of them converge and form bundles of fibres, which penetrate into the peripheral layer, and finally pierce the external limiting membrane, to emerge as the fascicles of the anterior nerve-roots. Behind the anterior horn the mantle layer still remains very thin, and the neuroblasts are few in number. There is, therefore, at this stage no appearance of the posterior horn of gray matter. Many of the axons of the neuroblasts which occupy this region are seen curving forwards, and, after traversing the anterior horn, they find their way across the middle line in the mid-ventral lamina. In this manner is laid down, at a very early stage, the rudiment of the anterior white commissure of the cord.

The white matter of the anterior and lateral columns is gradually established by axons from various neuroblasts in different parts of the mantle layer, entering the peripheral reticular layer and taking a longitudinal course within it. The anterior horn is well coated with white matter, however, before the lateral column takes definite shape.

The posterior columns of white matter are formed in a totally different manner, viz. by the introduction into the cord of nerve-fibres from without. The fibres of the posterior nerve-roots coming from the spinal ganglia strike the outer surface of the alar lamina of the lateral wall of the neural tube, and, piercing the external limiting membrane, take a longitudinal course in the peripheral reticular layer. On cross section these fibres first appear as an oval bundle, which lies in the outer part of the alar lamina (Fig. 379 PC). This bundle is the rudiment of Burdach's column, and at first it has a somewhat loose connexion with the cord; but as the posterior horn of gray matter gradually takes shape, the bundle in question increases in volume, and, changing its position, comes to lie on the inner aspect of the posterior horn. The column of Goll gradually assumes form between the tract of Burdach and the postero-median septum. Later on the lateral and anterior columns are increased in bulk by the descent into them of the pyramidal tracts from the brain.

The gray matter, in the first instance, is chiefly massed in the basal lamina; but as the posterior columns of white matter begin to take shape it extends backward, and in the course of time the posterior horns are developed.

The manner in which the dendritic processes of the neuroblasts are developed has been sufficiently described (p. 447). The ensheathment, also, of the axons by medulla has been referred to, and the fact that the different tracts of fibres receive their medullary sheaths at different periods mentioned. It is now only necessary to state that the order of myelinisation of the several tracts is as follows:—(1) Fibres of the anterior nerve-roots; (2) tract of Burdach; (3) fibres in the basis-bundles; (4) tract of Goll; (5) direct cerebellar tract; (6) tract of Gowers; (7) pyramidal tracts (Kahler).

Development of the Median Fissures and of the Central Canal.—As the anterior horns of gray matter covered by the anterior columns of white matter increase in size, the anterior surface of the cord on either side of the mesial plane bulges forwards, and the antero-median fissure is produced as the natural result.

The manner in which the postero-median fissure comes into existence is not fully understood, but the majority of embryologists believe that it is produced by the approximation and fusion of the walls of the posterior part of the primitive cavity of the neural tube. The postero-median septum would thus appear to be formed of spongioblastic tissue.

If the above view of the formation of the postero-median fissure be correct, it must be evident that the central canal of the cord does not represent the whole of the primitive cavity of the early neural tube, but only the anterior portion of it.

Among those observers who do not hold that the central canal and posterior fissure have this mode of origin the most prominent is Professor A. W. Robinson, of Birmingham; and he has brought forward evidence which seems to indicate that it is doubtful if the fusion of the walls of the posterior part of the canal, referred to above, takes place. Certainly the arrangement of the ependymal elements of the postero-median septum, as seen in the preparations of Cajal and v. Lenhossek, are extremely difficult to understand on the fusion theory. They run in the

antero-posterior direction, whereas, if fusion has taken place, most of them would present a transverse arrangement, and thus lie at right angles to the postero-median septum.

THE BRAIN OR ENCEPHALON.

The **brain** is the enlarged and greatly modified upper part of the cerebrospinal nervous axis. It is surrounded by the same membranes that envelop the spinal cord (viz. the dura mater, the arachnoid mater, and the pia mater), and it almost completely fills up the cavity of the cranium. So closely, indeed, is the skull capsule moulded upon the brain that the impress of the latter is almost everywhere evident upon the deep surface of the cranial wall. The relations, therefore, of cranium to brain are totally different from those presented by the vertebral canal

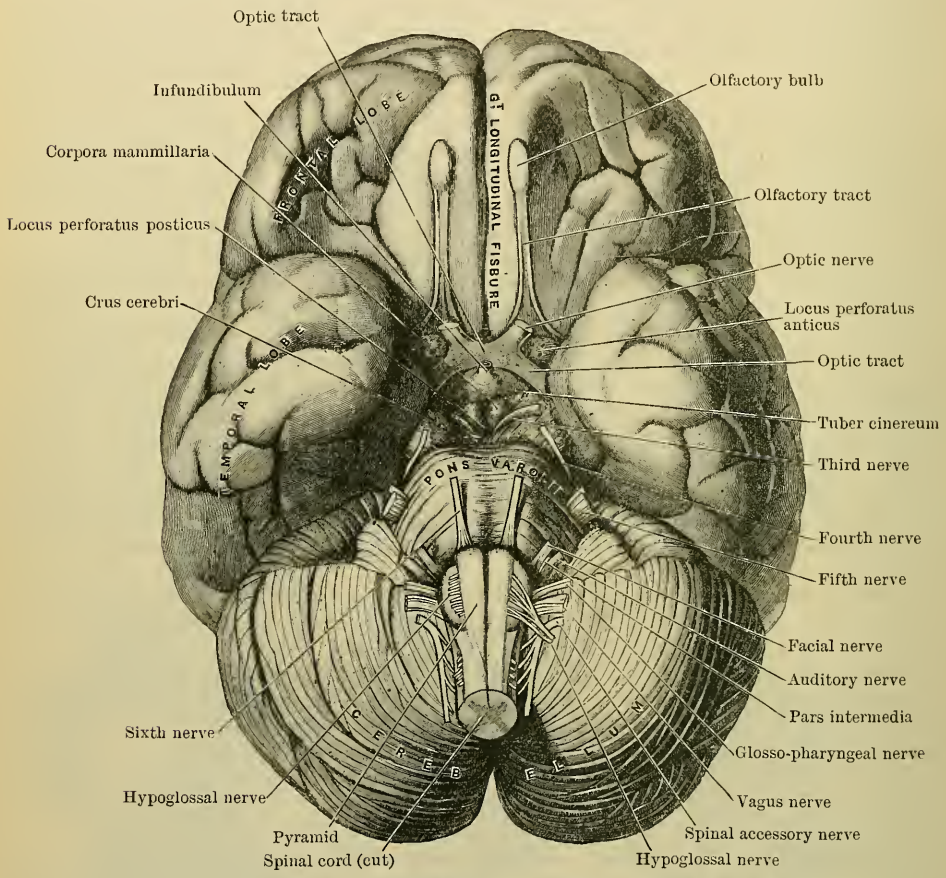


FIG. 380.—THE BASE OF THE BRAIN WITH THE CRANIAL NERVES ATTACHED.

to the spinal cord. As we have noted, the cord occupies only a part of its bony case; and there is not only a wide and roomy space between the arachnoid mater and pia mater, but also an interval of some width between the dura mater and the walls of the vertebral canal.

General Appearance of the Brain.—When viewed from above the brain presents an ovoid figure, the broad end of which is directed backwards. Its greatest transverse diameter is usually found in the neighbourhood of that part which lies between the two parietal eminences of the cranium. The only parts which are visible when the brain is inspected from this point of view are the two convoluted **cerebral hemispheres.** These present an extensive convex surface, which is closely applied to the deep aspect of the cranial vault, and are separated from each other by a deep median cleft, termed the **great longitudinal fissure,** which extends from the front to the back of the brain.

The inferior aspect of the brain is usually termed the "base." It presents an uneven and irregular surface, which is more or less accurately adapted to the inequalities on the floor of the cranium. Upon this aspect of the brain some of its main subdivisions may be recognised. Thus behind is seen the short cylindrical portion, called the **bulb** or **medulla oblongata**, through which, at the foramen magnum, the brain becomes continuous with the spinal cord. The bulb lies on the ventral aspect of the cerebellum, and occupies the vallecula or hollow which intervenes between the two cerebellar hemispheres. The **cerebellum** is a mass of considerable size which is placed below the hinder portions of the two cerebral hemispheres. It is easily recognised on account of the closely-set, curved, and parallel fissures which traverse its surface and give it a foliated appearance. Above the medulla, and in close connexion with it, is a prominent white elevation called the **pons Varolii**. Immediately in front of the pons there is a deep hollow or recess. This is bounded behind by the pons Varolii, on either side by the projecting temporal lobe of the cerebral hemisphere, and in front by the orbital portions of the frontal lobes of the cerebral hemispheres. Passing out from either side of the fore-part of this recess is the deep Sylvian fissure which intervenes between the pointed and projecting extremity of the temporal lobe and the frontal lobe of the cerebrum, whilst in the middle line in front the great longitudinal fissure, which separates the frontal portions of the cerebral hemispheres, opens into it.

Within the limits of this deep hollow, in the base of the brain, two large rope-like strands, the **crura cerebri**, may be seen issuing from the upper aspect of the pons Varolii. Placed close together as they emerge from the pons, these crura diverge as they proceed upwards and forwards, and finally each disappears by plunging into the corresponding side of the cerebrum. Turning round the outer side of each crus, where it enters the cerebrum, a flattened band termed the **optic tract** may be observed. These bands converge in the fore-part of the hollow, and are finally joined together by a short commissural portion, termed the **optic chiasma**. The **optic nerve** is continued forwards and outwards, on either side, from the chiasma and tract.

The crura cerebri, the optic tracts, and the optic chiasma enclose a deep rhomboidal or lozenge-shaped interval on the base of the brain, which is termed the **interpeduncular space**. Within the limits of this area the following parts may be seen as we pass from behind forwards: (1) the locus perforatus posticus; (2) the corpora mammillaria: (3) the tuber cinereum and the stalk of the pituitary body.

At its posterior angle, immediately in front of the pons Varolii, the interpeduncular space is very deep and is floored by a layer of gray matter, which is perforated by numerous small apertures. This is the **locus perforatus posticus**. Through the apertures which are dotted over its surface the small postero-mesial basal branches of the posterior cerebral artery enter the brain.

The **corpora mammillaria** are two small white pea-like eminences placed side by side in front of the locus perforatus posticus.

The **tuber cinereum** is a slightly raised field of gray matter, which occupies the interval between the anterior portions of the optic tracts in front of the corpora mammillaria. Springing from the fore-part of the tuber cinereum, immediately behind the optic chiasma, is the **infundibulum**, or the stalk which connects the pituitary body with the base of the brain.

Outside the limits of the fore-part of the interpeduncular space there is on either side a small depressed triangular field of gray matter, which leads outwards into the Sylvian fissure. It is perforated by the antero-mesial and the antero-lateral groups of basal arteries, and receives the name of the **locus perforatus anticus**.

General Connexions of the Several Parts of the Brain.—The medulla oblongata, the pons Varolii, and the cerebellum occupy the posterior cranial fossa, and they are separated from the cerebral hemispheres which lie above them by a partition of dura mater, termed the tentorium cerebelli. Further, they surround a cavity, a portion of the primitive cavity of the early neural tube, which is termed the **fourth ventricle** of the brain, and they all stand in intimate connexion with each other. The medulla is for the most part carried upwards into the pons

Varolii; but at the same time two large strands from its dorsal aspect, termed the restiform bodies, are prolonged into the cerebellum, and constitute its **inferior peduncles**, or the chief bonds of union between the medulla and the cerebellum. The pons Varolii has large numbers of transverse fibres entering into its composition, and the great majority of these are gathered together on either side in the form of a large rope-like strand. This plunges into the corresponding hemisphere of the cerebellum, and constitutes its **middle peduncle**.

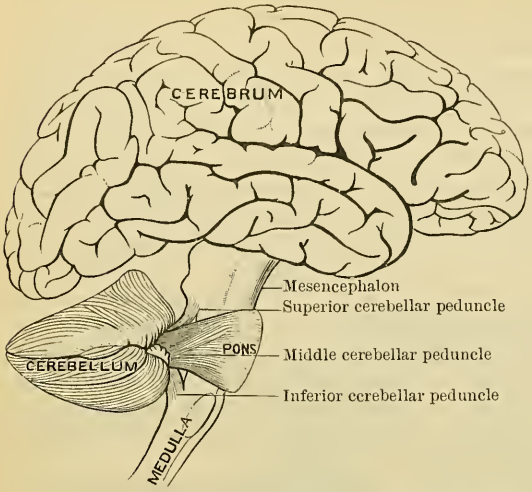


FIG. 381.—SCHEMA, showing the connexions of the several parts of the brain.

The cerebrum, which forms the great mass of the brain, occupies the anterior and middle cranial fossæ, and extends backwards into the occipital region above the tentorium and the cerebellum. The greater part of the cerebrum is formed by the cerebral hemispheres, which are separated from each other in the mesial plane by the great longitudinal fissure. At the bottom of this fissure is the **corpus callosum**, a broad commissural band which connects the two hemispheres with each other. Each hemisphere is hollow, the cavity in its interior being termed the **lateral ventricle** of the brain. Between and below the cerebral hemispheres, and almost completely concealed by them, is the **inter-brain** or **diencephalon**. The principal parts forming this portion of the brain are two large masses of gray matter, termed the **optic thalami**. Between these is the **third ventricle** of the brain—a deep narrow cavity occupying the mesial plane. The third ventricle communicates with the lateral ventricles by two small apertures, called the **foramina of Monro**.

The cerebrum is connected with the parts in the posterior cranial fossa (pons Varolii, cerebellum, and bulb) by a narrow stalk called the **mid-brain**, or **mesencephalon**. The mid-brain is built up of the **crura cerebri**, passing from the pons Varolii to the cerebrum; the **corpora quadrigemina**, forming its dorsal part; and the **superior cerebellar peduncles**, proceeding from the cerebellum to the cerebrum. It is tunnelled by a narrow passage, the **aqueduct of Sylvius**, which extends between the fourth and third ventricles.

General Outline of the Development of the Brain.

The brain is developed from the expanded anterior portion of the primitive neural tube. In the section dealing with the general principles of Embryology it has been pointed out that this part of the neural tube is marked off by two constrictions into three primitive cerebral vesicles, which are termed respectively the hind-brain or rhombencephalon, the mid-brain or mesencephalon, and the fore-brain or prosencephalon.

Hind-brain or Rhombencephalon.—The hind-brain is the largest of the three primary expansions of the neural tube: indeed, it may be said that in the earlier stages of brain development it is larger than both of the other primary subdivisions taken together. The portion immediately adjoining the mid-brain is constricted, and is termed the **isthmus rhombencephali**. This is a very small part, forming the extreme upper end of the vesicle, and from its walls are developed the superior cerebellar peduncles and a thin lamina, which is stretched across the middle line between them, called the valve of Vieussens or the superior medullary velum. Immediately behind the isthmus the hind-brain expands suddenly, and then slowly and gradually tapers as it passes downwards towards the spinal cord part of the neural tube. Its junction with the latter is very early indicated by a sharp bend

in the tube, which is termed the **cervical flexure.** The large portion of hind-brain which extends from the isthmus to the cervical flexure is usually considered as being composed of two parts, viz. an upper portion, termed the metencephalon, and an inferior portion, called the myelencephalon.

From the **metencephalon** are derived the cerebellum and pons Varolii. The cerebellum arises by a thickening of the dorsal wall of this portion of the vesicle, whilst the pons is formed by a thickening of the lateral and ventral walls. The

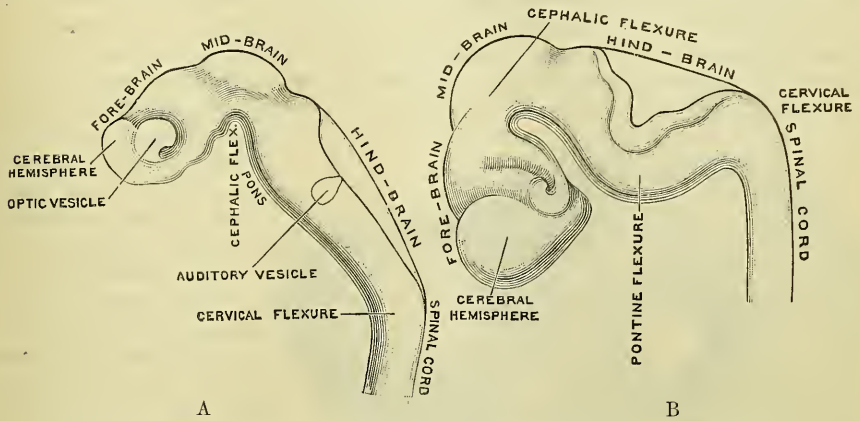


Fig. 382.—Two Stages in the Development of the Human Brain (after His).

A. Brain of an embryo of the third week. B. Brain of an embryo of five weeks.

myelencephalon gives origin to the bulb or medulla oblongata. This is chiefly formed by a thickening of the lateral walls of this part of the vesicle. These fall away from each other in an outward direction, and thus the ventral angle between them becomes greatly opened up. The growth which leads to the formation of the bulb appears, therefore, to take place chiefly on the ventral aspect of the vesicle. The dorsal wall remains thin and epithelial, and undergoes little or no development into nervous elements.

The cavity of the original hind-brain is retained in the adult brain as the fourth ventricle; and from what has been said regarding the development of the different portions of the wall of the primitive hind-brain, it will be seen that in its lower or medullary part its dorsal wall or roof, to a large extent, remains epithelial.

The parts of the adult brain which are derived from the rhombencephalon or hind-brain are those which lie below the tentorium cerebelli in the posterior cranial fossa of the skull.

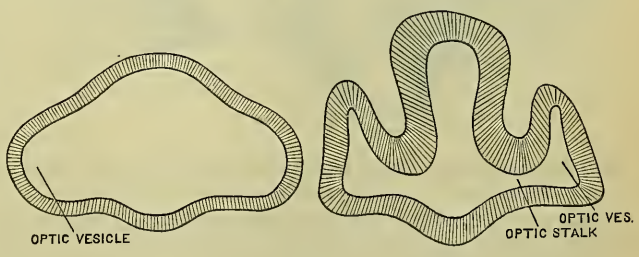


Fig. 383.—Two Cross Sections through the Fore-Brain.

A. Through the fore-brain of the early human embryo. B. Through the fore-brain and optic vesicles of a Lepidosteus embryo of eight days (after Balfour and Parker, modified).

Mesencephalon or Mid-brain.—The mid-brain takes a much more prominent part in the formation of the early primitive brain than it does in the construction of the adult brain. It forms a very small part of the adult brain, and constitutes a stalk of connexion between the parts which are developed from the walls of the rhombencephalon and those which are developed from the walls of the prosencephalon or fore-brain. The entire wall of the mid-brain is transformed into nervous tissue. Thus, by the special development of the dorsal section of the wall, the corpora quadrigemina are formed. The lateral and ventral sections of the wall undergo a still more marked degree of growth-thickening, and the result is the

formation of the two crura cerebri. The cavity of the mid-brain is retained as the narrow passage termed the aqueduct of Sylvius, which connects the third ventricle of the brain with the fourth ventricle.

Prosencephalon or Fore-brain.—In its early condition one of the leading peculiarities of the fore-brain is its great width. It extends outwards on either side for a considerable distance beyond the lateral walls of the mid-brain. These lateral expansions of the fore-brain are the **optic vesicles**, and at this stage they are in no way constricted off from the central part of the cavity (Fig. 383). Soon, however, the central portion of the fore-brain begins to expand upwards and forwards, whilst the terminal portions of the optic vesicles likewise undergo enlargement; and the result is, that the originally single chamber shows subdivision into three parts, viz. a central portion or fore-brain proper, and two expanded optic vesicles, which are joined to the lower parts of the lateral aspects of the fore-brain proper by two short constricted tubular passages termed the **optic stalks**.

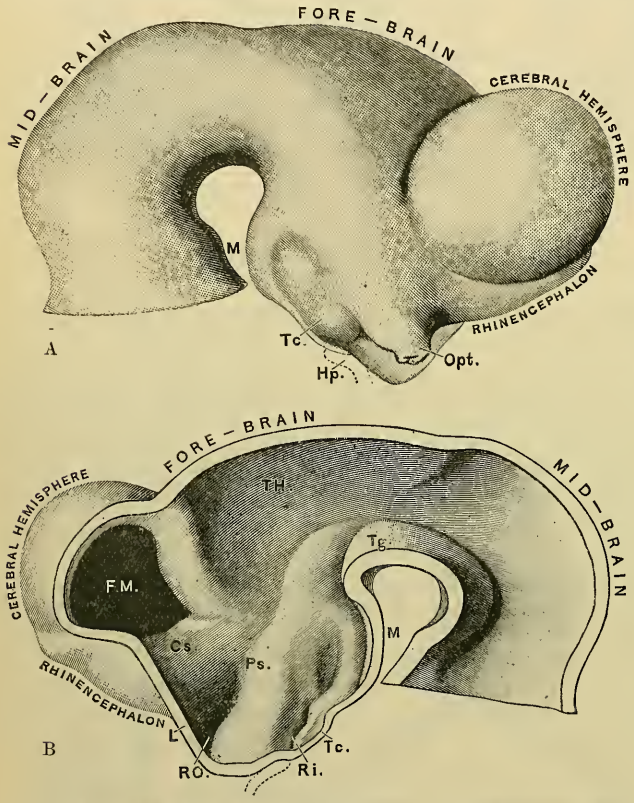


Fig. 384.—The Brain of a Human Embryo in the Fifth Week (from His).

A, Brain as seen in profile. B, Mesial section through the same brain. M, Mammillary eminence; Tc. Tuber cinereum; Hp, Hypophysis (pituitary diverticulum from buccal cavity); Opt, Optic stalk; TH, Optic thalamus; Tg, Tegmental part of mesencephalon; Ps, Pars subthalamica; Cs, Corpus striatum; FM, Foramen of Monro; L, Lamina terminalis; RO, Recessus opticus; Ri, Recessus infundibuli.

The optic vesicle and the optic stalk become ultimately transformed into the retina of the eye-ball and the optic nerve. The changes which lead to this result are detailed in the section dealing with the anatomy of the organ of vision.

The fore-brain undergoes a series of remarkable developmental changes, the most striking of which is the formation of the cerebral hemispheres. The terminal or fore-portion of the fore-brain, in the first instance, expands in a forward and downward direction, and from the upper and lateral aspects of the new portion of the vesicle thus formed the cerebral hemispheres bulge outwards in the form of two hollow pouches. The hinder original part of the fore-brain is termed the **thalmamencephalon** or **diencephalon**, whilst the anterior part with the cerebral hemispheres, which protrude out from it, receives the name of **telencephalon**.

The side walls of the diencephalon become thickened into the two large masses of gray matter termed the optic thalami; the floor or ventral wall develops into those structures which occupy the interpeduncular space in the base of the brain (viz. the posterior perforated spot, the corpora mammillaria, and the tuber cinereum); whilst the roof or dorsal wall remains thin and epithelial, and undergoes no nervous development.

The hollow cerebral hemispheres soon outstrip all the other parts of the brain in their development. They expand not only in an upward and forward direction,

but chiefly in a backward direction; and by their excessive growth backwards they gradually come to overlie the diencephalon, the mesencephalon, and at last the parts derived from the rhombencephalon. It thus comes about that, when the adult brain is viewed from above nothing but the cerebral hemispheres are visible—all the other parts of the brain lie under cover of them.

At first the cavity of each cerebral hemisphere is connected with the cavity of the front portion of the fore-brain by an exceedingly short but relatively wide passage. This is the early condition of the **foramen of Monro.** The fore-part of the fore-brain is now seen to be bounded in front between the two hollow cerebral hemisphere-pouches by a narrow thin strip, which represents the extreme anterior wall of the neural tube, and consequently it receives the name of **lamina terminalis.** The cavity of the fore-brain not only in its hinder diencephalic part, but also in its anterior telencephalic part (*i.e.* the part from which the cerebral hemispheres bud out), persists as the third ventricle of the brain, whilst the cavities of the primitive cerebral hemispheres are represented in the adult by the lateral ventricles of the brain. The foramina of Monro, relatively much reduced in size, are preserved as narrow throats of communication between the lateral ventricles and the third ventricle. The olfactory lobes are formed as hollow outgrowths from the cerebral hemispheres.

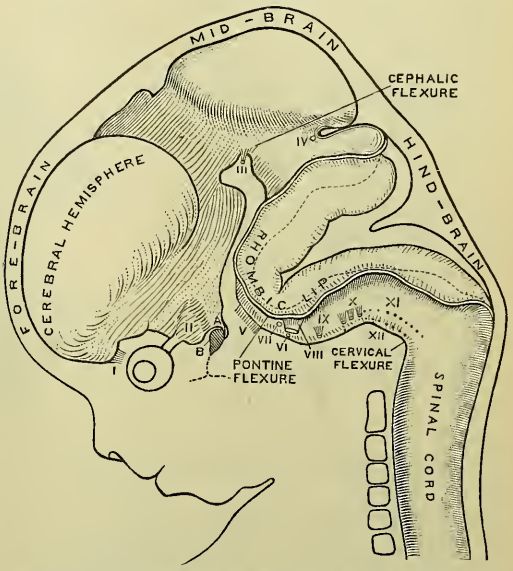


FIG. 385.—PROFILE VIEW OF THE BRAIN OF A HUMAN EMBRYO OF TEN WEEKS (His).

The various cranial nerves are indicated by numerals.

A, Cerebral diverticulum of pituitary body. B, Buccal diverticulum of pituitary body.

Flexures of the Brain-tube.—At a very early period, and while the changes detailed above are being carried on, the cerebral portion of the neural tube becomes sharply bent upon itself at certain points. The first flexure which occurs is the **primary cephalic flexure.** It occurs in the region of the mesencephalon, and involves the entire head. The fore-brain becomes bent in a ventral direction round the fore-end of the notochord and the fore-gut, until the long axis of the fore-brain forms an acute angle with the long axis of the hind-brain and the ventral wall of the one comes to lie nearly parallel with the corresponding wall of the other. Through this curvature the mid-brain is considerably modified in form, and for a time it comes to occupy the most prominent and foremost part of the embryonic head.

The primary cephalic flexure is soon followed by the **cervical flexure.** This occurs at the junction of the hind-brain with the spinal cord. Here the entire head is bent in a ventral direction, and at the end of the fifth week the flexure is so pronounced that the cerebral and spinal cord portions of the neural tube meet each other at a right angle (Fig. 385). In the later stages of development the cervical flexure becomes obliterated by the elevation of the head and the straightening of the neck of the embryo.

The third bend takes place in the region of the future pons Varolii (metencephalon), and is consequently termed the **pontine flexure.** It differs from the other flexures in being confined to the brain tube and in not in any way involving the entire head. Further, the bend is much more marked in the thick ventral wall than in the thin dorsal wall of the tube. The neural tube is doubled forwards on itself and the pons Varolii becomes developed in connexion with the summit of the curvature. In the further growth of the brain the pontine flexure becomes almost completely obliterated.

By reason of these curvatures the early brain assumes a sinuous, zigzag or S-shaped outline when viewed from the side, and the relationship of its various parts becomes materially altered. The essential factor at work in the production of the brain flexures is clearly the very unequal growth which takes place in different parts of the cerebral wall.

Basal and Alar Laminæ of His.—It has been pointed out that, in the development of the spinal cord, each of the thick lateral walls of the neural tube is marked off into a dorsal or alar and a ventral or basal lamina. This subdivision is also noticeable in the cerebral part of the neural tube, and the furrow on the inner aspect of the lateral wall, which indicates this subdivision, can be traced even in the adult brain throughout a considerable part of its length.

In the spinal cord the motor cells are gathered in the basal lamina in more or less continuous columns. In the brain the corresponding cells from which the efferent fibres of the cranial nerves are given off are also placed within the basal lamina, but they are arranged differently. They are collected together in disconnected clusters termed the motor nuclei, and they do not extend higher up than the mid-brain. No motor nuclei occur in the fore-brain. Indeed, the importance of the basal lamina diminishes as we pass from the lower to the higher parts of the brain.

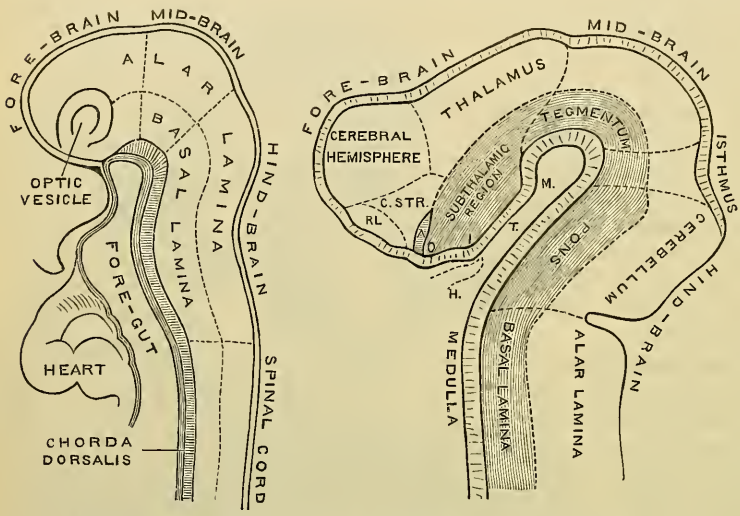


Fig. 386.—Diagrams to illustrate the Alar and Basal Laminæ. In both cases the embryonic brain is represented in mesial section (His).

A. The different subdivisions of the brain are marked off from each other by dotted lines, and the dotted line running in the long axis of the neural tube indicates the separation of the alar from the basal lamima of the lateral wall.

B. Mesial section through the brain of a human embryo at the end of the first month. Dotted lines mark off the different regions and also the alar and basal laminæ from each other.

H, Buccal part of pituitary body; RL, Olfactory lobe; C.Str, Corpus striatum; A, Entrance to optic stalk; O, Optic recess; I, Infundibular recess; T, Tuber cinereum; M. Mammillary eminence.

In the rhombic or hind-brain the greater part of the medulla oblongata and of the pons Varolii is formed from the basal laminæ, whilst the cerebellum, with its superior and inferior cerebellar peduncles, is derived from the alar laminæ. In the mid-brain the crura cerebri are the derivatives of the basal laminæ, whilst the corpora quadrigemina are developed from the alar laminæ. In the fore-brain the subthalamic region and the optic vesicles are products of the growth of the basal laminæ, whilst the optic thalami and cerebral hemispheres spring from the alar laminæ.

The fact that the cerebellum and the cerebral hemispheres owe their origin to the alar laminæ is sufficient to show the predominant part which these laminæ play in brain development, and the higher we ascend in the animal scale the more pronounced does this predominance become.

The following table gives a summary of the various developmental processes which have been described in the foregoing pages:—

Encephalon or Brain	Rhombencephalon or Hind-brain (posterior cerebral vesicle)	Myelencephalon	Bulb or medulla oblongata Lower part of the fourth ventricle
		Metencephalon	Cerebellum Pons Varolii Upper part of the fourth ventricle
		Isthmus rhombencephali (narrow constricted part immediately adjoining the mesencephalon)	Superior cerebellar peduncles Valve of Vieussens
	Mesencephalon or Mid-brain (middle cerebral vesicle)	Mesencephalon or Mid-brain	Corpora quadrigemina Crura cerebri Aqueduct of Sylvius
	Prosencephalon or Fore-brain (anterior cerebral vesicle)	Thalamencephalon or Diencephalon	Optic thalami Subthalamic tegmental regions Pituitary and pineal bodies Structures in interpeduncular space Optic nerve and retina Hinder part of the third ventricle
		Telencephalon	Cerebral hemispheres Olfactory lobes Lateral ventricles Foramina of Monro Anterior portion of the third ventricle

THE PARTS OF THE ENCEPHALON DERIVED FROM THE HIND-BRAIN.

MEDULLA OBLONGATA OR BULB.

The **medulla oblongata** or **bulb** is the continuation upwards of the spinal cord. It is not more than one inch in length, and it may be regarded as beginning at the decussation of the pyramidal tracts, which takes place about the level of the foramen magnum. From this it proceeds upwards in a very nearly vertical direction, and ends at the lower border of the pons Varolii. At first its girth is similar to that of the cord, but it rapidly expands as it approaches the pons, and consequently it presents a more or less conical form. Its ventral surface lies behind the grooved surface of the basilar portion of the occipital bone, whilst its dorsal surface is sunk into the vallecula of the cerebellum. The medulla oblongata is a bilateral structure, and this is indicated on the surface by a continuation upwards of the antero-median and postero-median fissures of the cord on the ventral and dorsal aspects of the medulla.

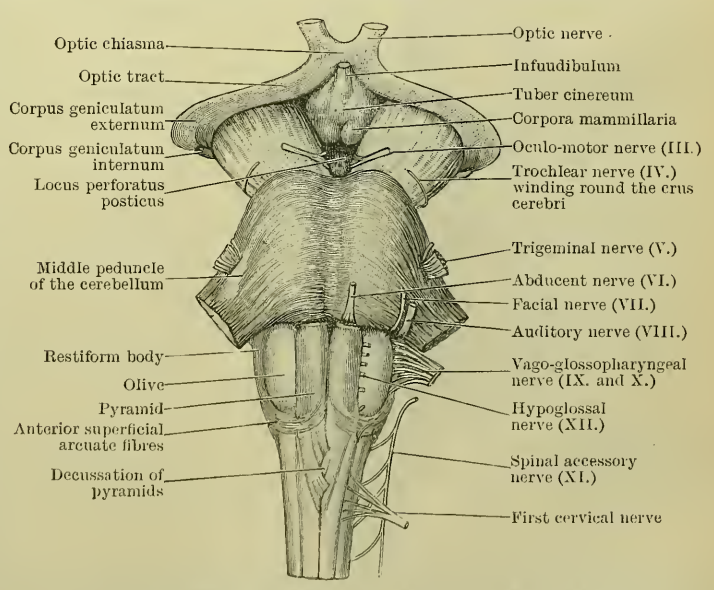


Fig. 387.—Front View of the Medulla, Pons, and Mesencephalon of a full-time Human Fœtus.

The **antero-median groove** (fissura mediana anterior), as it passes from the cord on to the medulla, is interrupted at the level of the foramen magnum by several strands of fibres, which cross the mesial plane from one side to the other. This intercrossing is termed the decussation of the pyramids. Above this level the furrow is carried upwards to the lower border of the pons, but is often rendered very shallow by numerous superficial arcuate fibres which emerge upon the surface between its lips and then curve outwards to reach the hinder part of the medulla. At the lower margin of the pons Varolii it expands slightly and ends in a blind pit, which receives the name of the **foramen cæcum** of Vicq d'Azyr. The **postero-median fissure** (fissura mediana posterior) is only carried up on the lower half of the medulla. As it ascends it rapidly becomes shallower, and, halfway up, the central canal of the cord opens on the dorsal surface of the medulla. At this point the lips of the postero-median fissure are thrust apart from each other and constitute the boundaries of a triangular field, which is thus opened up on the dorsal aspect of the medulla. This triangular field is the lower part of the **fossa rhomboidalis**, or the floor of the fourth ventricle of the brain. The lower half of the medulla, containing as it does the continuation of the central canal of the cord, is frequently termed the **closed part of the medulla**; the upper half, above the opening of the canal, which by its dorsal surface forms the lower part of the floor of the fourth ventricle, is then called the **open part of the medulla.**

Deferring for the present the examination of the medullary part of the floor of the fourth ventricle, the appearance presented by the surface of each side of the medulla, from the antero-median fissure in front to the postero-median fissure and the lateral limit of the floor of the fourth ventricle behind, may now engage our attention. In the spinal cord the corresponding surface area is divided into three districts or columns by the emerging motor roots and the entering sensory roots of the spinal nerves. Of these the latter enter along the bottom of the postero-lateral groove, whilst the motor fascicles are spread over a relatively broad surface area and have no groove in connexion with their emergence from the cord. In the case of the medulla corresponding rows of nerve-fascicles enter and emerge from the surface of each side. The efferent fascicles are the root-bundles of the hypoglossal nerve, and they carry up the line of the anterior nerve-roots of the cord. In one respect, however, they differ: they emerge in linear order and along the bottom of a distinct furrow, termed the **antero-lateral furrow,** which proceeds upwards on the surface of the medulla. The fascicles which carry up the line of the posterior nerve-roots on the surface of the medulla are the root-bundles of the spinal accessory, the vagus, and the glosso-pharyngeal nerves. These are attached along the bottom of a furrow which is the direct continuation upwards of the postero-lateral furrow of the cord, and therefore receives the name of the **postero-lateral furrow** of the medulla. The root-bundles

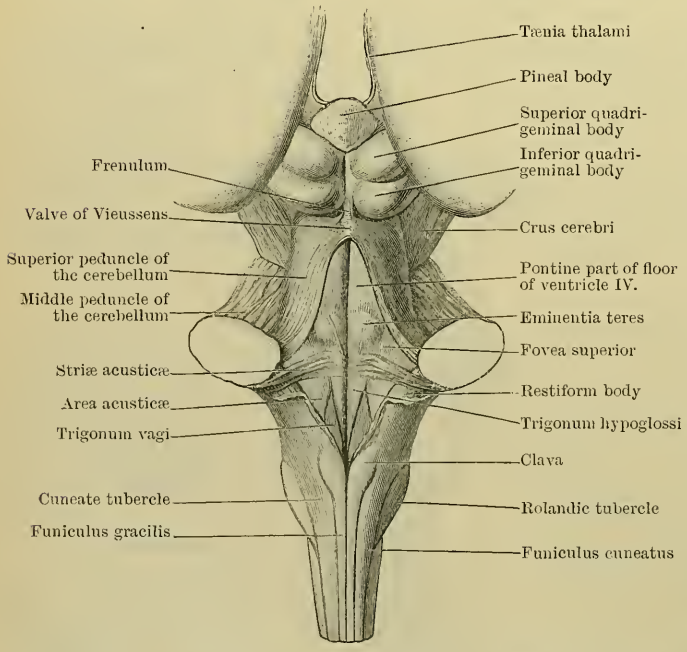


FIG. 388.—BACK VIEW OF THE MEDULLA, PONS, AND MESENCEPHALON OF A FULL-TIME HUMAN FŒTUS.

of these nerves differ, however, in so far that they are not all composed of afferent fibres springing from ganglionic cells placed without and entering the medulla. Certain of them are purely efferent (spinal accessory roots), whilst others likewise contain a considerable number of efferent fibres, and are therefore to be regarded as mixed roots.

By the postero-lateral and the antero-lateral grooves, and also by the two rows of nerve fascicles attached along the bottom of these furrows, the surface of the medulla on each side is divided into three districts, viz. an anterior, a lateral, and a posterior, similar to the surface areas of the three columns on the side of the cord. Indeed, at first sight, they appear to be a direct continuation upwards of these three portions of the cord; this is not the case, however, because the fibres of the three columns of the cord undergo a rearrangement as they proceed upwards into the medulla.

Anterior Area of the Medulla—Pyramid (pyramis).—The district between the antero-median fissure and the antero-lateral furrow, along the bottom of which the root-fascicles of the hypoglossal nerve issue from the medulla, receives the name of the pyramid. An inspection of the surface is sufficient to show that the pyramid is composed of a compact strand of longitudinally directed nerve-fibres. Tapering below, it expands and assumes a prominent appearance as it is traced upwards, and, finally reaching the lower border of the pons Varolii, it becomes slightly constricted and disappears from view by plunging into that portion of the brain. The two pyramids, separated from each other by the antero-median furrow, are the great motor strands of the medulla.

Although the pyramid at first sight appears to be continuous with the anterior column of the cord, only a very small proportion of the fibres contained in the latter are derived from the pyramid. This at once becomes manifest when the lips of the antero-median fissure are thrust apart at the place of junction between the cord and the medulla. The pyramid is then seen to divide at this level into two parts, viz. a small portion composed of a variable number of the outermost fibres of the pyramid, termed the **direct pyramidal tract**, and a much larger portion situated next the antero-median fissure, called the **crossed pyramidal tract.** The direct pyramidal tract is continued down into the anterior column of the cord, and in this it takes up a mesial position next the antero-median fissure. The crossed pyramidal tract is broken up into three or more coarse bundles, which sink backwards and at the same time cross the mesial plane, to take up a position in the posterior part of the opposite lateral column of the cord. The term **decussation of the pyramids** (decussatio pyramidum) is applied to the intercrossing of the corresponding bundles of the crossed pyramidal tracts of opposite sides.

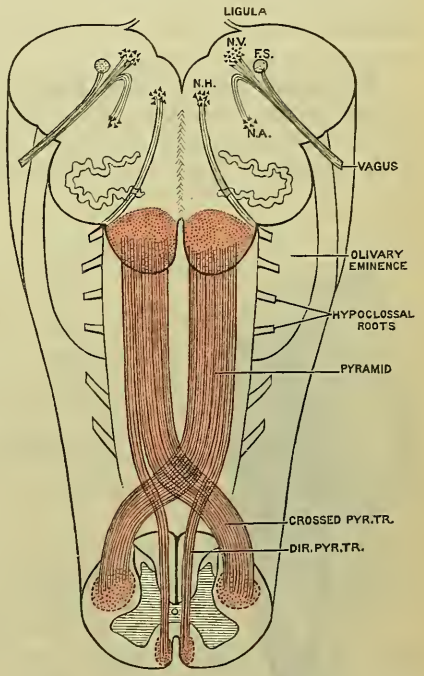


FIG. 389.—DIAGRAM OF THE DECUSSATION OF THE PYRAMIDS (modified from van Gehuchten).

NH, Nucleus hypoglossi; NV, Vago-glosso-pharyngeal nucleus; FS, Fasciculus solitarius; NA, Nucleus ambiguus.

The direct pyramidal tract is, therefore, the only part of the pyramid which has a place in the anterior column of the cord. The much larger part of this column, termed the anterior basis-bundle, as it is traced up into the medulla is seen to be thrust aside by the decussating bundles of the crossed pyramidal tract. It thus comes to occupy a deep position in the substance of the medulla behind and to the outer side of the pyramid.

Lateral Area of the Medulla.—This is the district on the surface of the medulla

which is included between the two rows of nerve-roots, viz. the hypoglossal roots in front, and the root-bundles of the spinal accessory, the vagus, and the glosso-pharyngeal nerves behind. It presents a very different appearance in its upper and lower parts. In its lower portion it simply appears to be a continuation upwards of the lateral area of the cord; in its upper part a striking oval prominence bulges out on the surface of the medulla, and receives the name of the **olivary eminence.**

The lower part of this district, however, is very far from being an exact counterpart of the lateral column of the cord. The large crossed pyramidal tract is no longer present, seeing that it forms in the medulla the greater part of the pyramid of the opposite side. Another strand of fibres, viz. the direct cerebellar tract, prolonged upwards in the lateral column of the cord, gradually leaves this portion of the medulla. This tract lies on the surface, and is frequently visible to the naked eye as a white band, which inclines obliquely backwards into the posterior district of the medulla to join its upper part, or in other words the restiform body. The remainder of the fibres of the lateral column of the cord, comprising the lateral basis-bundle and the tract of Gowers, are continued upwards in the lateral area of the medulla, and at the lower border of the olive the majority of these fibres disappear from the surface by dipping into the substance of the medulla under cover of that projection. A small proportion of the fibres, however, are retained on the surface and travel upwards towards the pons in the interval, which exists between the hinder border of the olive and the roots of the vagus and glosso-pharyngeal nerves.

The **olivary eminence** (oliva) is a smooth oval projection which bulges out from the upper part of the lateral area of the medulla. Its long axis is vertical and is about half an inch long. It marks the position of the subjacent **inferior olivary nucleus**, a flexuous lamina of gray matter (nucleus olivaris inferior), which is only separated from the surface by a very thin layer of superficial white matter.

Posterior Area of the Medulla.—In its lower half, this district is bounded behind by the postero-median fissure, and in its upper half by the lateral margin of the medullary part of the floor of the fourth ventricle of the brain. In front it is separated from the lateral area by the row of root-fascicles belonging to the spinal accessory, vagus, and glosso-pharyngeal nerves. As in the lateral area, we recognise a lower portion and an upper portion, which appear continuous but in reality are almost quite distinct from each other.

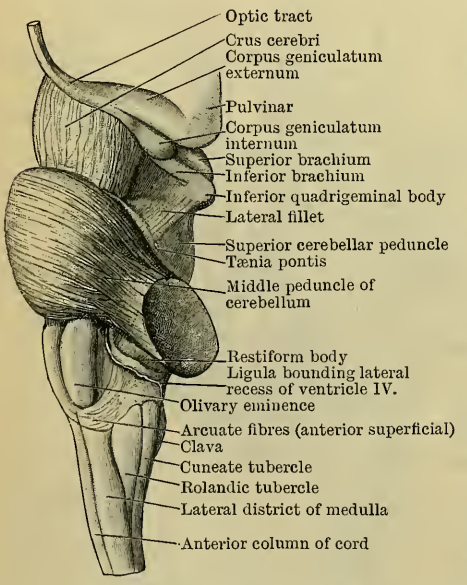


FIG. 390.—LATERAL VIEW OF THE MEDULLA, PONS, AND MESENCEPHALON OF A FULL-TIME HUMAN FŒTUS.

The lower part of the posterior area corresponds more or less closely with the posterior column of the cord. In the cervical part of the cord the posterior column is divided by the paramedian septum of pia mater into an inner column of Goll and an outer column of Burdach. These are prolonged upwards into the medulla, and in the lower part of the posterior area they stand out distinctly, and are separated from each other by a continuation upwards from the cord of the paramedian groove. In the medulla the inner of these strands is called the **funiculus gracilis**, whilst the outer one is designated the **funiculus cuneatus.** Each of these strands, when it reaches the level of the lower part of the floor of the fourth ventricle, ends in a slightly expanded bulbous prominence. The swollen extremity of the funiculus gracilis is called the **clava.** This is thrust aside from its neighbour of the opposite side by the opening up of the medulla to form the floor of the fourth ventricle, and the central canal of

the cord opens on the surface in the angle between the two clavæ. The bulbous end of the fasciculus cuneatus receives the name of the **cuneate tubercle** (tuberculum cinereum), but it is only in the fœtal or very young brain that it is well marked.

The elongated prominences formed on the surface of the medulla by these two strands and their enlarged extremities are, in a great measure, due to the presence of two elongated nuclei or collections of gray matter which make their appearance subjacent to the strands, and which gradually increase in bulk as they are traced upwards. These are termed respectively the **gracile** (nucleus funiculi gracilis) and **cuneate** (nucleus funiculi cuneati) **nuclei**, and it can be easily shown that as the gray matter increases in quantity the fibres of the two corresponding strands diminish in number by coming to an end in connexion with the cells of the subjacent nuclei. Indeed, it is doubtful if any of the fibres of the gracile and cuneate strands extend upwards beyond these nuclei.

But a third longitudinal elevation is also apparent on the surface of the lower part of the posterior area of the medulla. This is placed on the outer side of the funiculus cuneatus—between it and the posterior row of nerve-roots—and it has no counterpart in the posterior column of the cord. It is called the **funiculus of Rolando**, because it is produced by the substantia gelatinosa Rolandi, which caps the posterior horn, coming close to the surface and forming a bulging in this situation. The funiculus of Rolando is wedge-shaped in outline. Extremely narrow below, it widens as it is traced upwards, and finally ends in an expanded extremity called the **tubercle of Rolando** (tuberculum Rolandi). A thin layer of white matter, composed of longitudinally arranged fibres, is spread over this district, and separates the substantia Rolandi from the surface. These fibres constitute the spinal root of the fifth or trigeminal nerve, which here assumes a superficial position as it descends in the medulla.

The **restiform body** (corpus restiforme) forms the upper part of the posterior area of the medulla. It lies between the floor of the fourth ventricle and the roots of the vagus and glosso-pharyngeal nerves. It is a large and prominent rope-like strand, which inclines upwards and outwards, and then finally takes a turn backwards and enters the cerebellum. It forms the great link of connexion between the cerebellum on the one hand and the medulla and spinal cord on the other, and consequently it also receives the name of the **inferior cerebellar peduncle**. At the same time it must be understood that it is not formed by fibres which are prolonged into it from the funiculus cuneatus and funiculus gracilis of the medulla. It is true that a surface inspection of the medulla might very naturally lead the observer to this supposition, because there is no sharp line of demarcation marking it off from the tubercles of these strands. Such a conclusion, however, would be altogether erroneous, because it would appear that none of the fibres of the posterior columns of the cord are carried beyond the gracile and cuneate nuclei of the medulla. A study of the surface of the medulla yields some important information regarding the constitution of the restiform body. Thus the direct cerebellar tract from the lateral column of the cord can be traced into it, and large numbers of fibres which take a curved course on the surface of the medulla may likewise be followed into it. These are the superficial arcuate fibres. Numerous other fibres enter the restiform body on its deep aspect, but these will be studied at a later stage.

Superficial Arcuate Fibres (fibræ arcuatæ externæ).—These fibres enter into the constitution of the restiform body, and they may be regarded as consisting of two sets, viz. the anterior superficial arcuate fibres and the posterior superficial arcuate fibres, both of which present this feature in common that they run on the surface of the medulla.

The **anterior superficial arcuate fibres** are more particularly seen in the neighbourhood of the olivary eminence, round the lower border of which, and also over the surface of which, they may be observed coursing in the form of a number of coarse curved bundles. They vary greatly in number and in distinctness, and they are sometimes so numerous as to cover over almost entirely the eminence. An attentive examination will show that they come to the surface in the antero-median fissure between the pyramids, and also not unfrequently in the groove between the

pyramid and olive, or through the substance of the pyramid itself. The antero-median fissure in its upper part is often almost completely blocked up by these emerging fibres. The anterior superficial arcuate fibres reaching the surface of the medulla in this manner turn backwards, and the great majority enter the restiform body and form a considerable part of its outer portion.

The **posterior superficial arcuate fibres** arise in the cuneate and gracile nuclei, and enter the restiform body of the same side.

THE PONS VAROLII.

The **pons Varolii** is a marked white prominence on the basal aspect of the brain which is interposed between the medulla and the crura cerebri, and which lies in front of the cerebellum. It is convex from side to side, as well as from above downwards, and transverse streaks on its surface show that, superficially at least, it is composed of bundles of nerve-fibres which course transversely over it. On either side these transverse fibres are collected together in the form of a large compact strand, which sinks in a backward and outward direction into the white matter of the corresponding hemisphere of the cerebellum. This strand is termed the **middle peduncle of the cerebellum**, and the term "pons," applied to the entire structure, expresses in an admirable way the arch-like manner in which this portion of the brain bridges across between the two cerebellar hemispheres.

The *ventral surface* of the pons is in relation to the basilar process of the occipital bone and the dorsum sellæ of the sphenoid bone. It presents a mesial groove (sulcus basilaris), which gradually widens as it is traced upwards, and in which the basilar artery lies. This mesial depression is produced by the prominence which is caused on either side by the passage of the pyramidal tract of fibres downwards through the pons. The **trigeminal** or fifth cranial nerve, with its large entering sensory root and its small emerging motor root, is attached to the side of the ventral aspect of the pons, nearer its upper than its lower border. It is usual to restrict the term "pons" to that portion of the structure which lies between the two trigeminal nerves, and to apply the designation of middle cerebellar peduncle to the part which extends beyond the nerve into the hemisphere of the cerebellum. The sixth or **abducent nerve**, the seventh or **facial nerve**, and the eighth or **auditory nerve** are attached to the brain at the lower border of the pons. The sixth emerges at the outer border of the pyramid, the seventh immediately in front of the restiform body, whilst the auditory nerve reaches the brain close to the facial nerve, on the ventral aspect of the restiform body.

The whole of the medulla enters the *lower aspect* of the pons, and, with the exception of the restiform bodies, its constituent parts are, to a large extent, carried up within it. The crura cerebri emerge from its *upper aspect*.

The *dorsal surface* of the pons looks backwards towards the cerebellum, and presents a triangular area covered with gray matter, which forms the upper part of the anterior wall or floor of the fourth ventricle. This area is directly continuous below with the medullary part of the floor of the fourth ventricle, and is bounded on either side by a band of white matter termed the **superior peduncle of the cerebellum.**

Superior Cerebellar Peduncles (brachia conjunctiva).—These are hidden from view by the upper part of the cerebellum, under cover of which they lie. They emerge from the lateral hemispheres of the cerebellum, and, as they proceed upwards on the dorsal aspect of the pons, they converge towards each other until, at the level of the inferior corpora quadrigemina, the inner margins of the two peduncles almost become contiguous (Fig. 388, p. 482). At first they form the lateral boundaries of the upper part of the fourth ventricle; but, as they ascend and approach closer to each other, they gradually come to overhang that cavity and thus enter into the formation of its roof. They disappear from the surface by dipping under cover of the quadrigeminal bodies and entering the substance of the mesencephalon.

Valve of Vieussens or the Superior Medullary Velum (velum medullare anterius).—Filling up the triangular interval between the two superior cere-

bellar peduncles, and stretching across from the inner and free margin of the one to the corresponding margin of the other, is a thin layer of white matter which completes the roof or dorsal wall of the upper part of the fourth ventricle, and receives the name of the superior medullary velum. When traced downwards, it is seen to be carried with the superior peduncles into the white matter of the cerebellum. Spread out on its dorsal surface is a small, thin, tongue-shaped prolongation of gray matter from the cortex of the cerebellum, which is termed the **lingula**, whilst issuing from its substance close to the inferior quadrigeminal bodies are the two **fourth** or **trochlear cranial nerves.**

Fourth Ventricle of the Brain (ventriculus quartus).—The fourth ventricle is somewhat rhomboidal in form. Below, it tapers to a point and becomes continuous with the central canal of the cord; above, it narrows in a similar manner and is continued into the aqueduct of Sylvius, which tunnels the mesencephalon. The posterior wall is termed the **roof** and is concealed by the cerebellum. The anterior wall is called the **floor** and is formed by the dorsal surfaces of the medulla and pons. On either side a long, curved and narrow prolongation of the ventricular cavity is carried outwards from its widest part and curves round the upper part of the corresponding restiform body. This is termed the **lateral recess.** The roof of the cavity is very thin and intimately connected with the cerebellum. It is better, therefore, to defer its description until that part of the brain has been studied.

Floor of the Fourth Ventricle (fossa rhomboidea).—In its lower part the floor of the fourth ventricle is formed by the dorsal surface of the open part of the

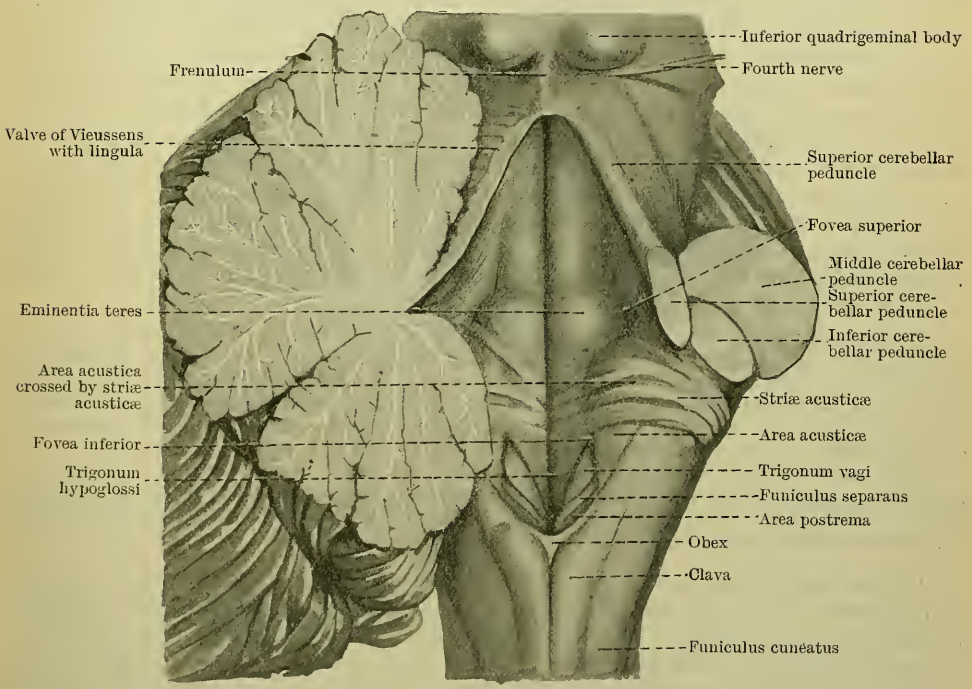


FIG. 391.—FLOOR OF THE FOURTH VENTRICLE. On the right side the right half of the cerebellum has been removed by cutting through its three peduncles and dividing it in the mesial plane. On the left side the left half of the cerebellum is drawn over to the left so as to expose fully the floor of the ventricle.

medulla, whilst in its upper part it is formed by the dorsal surface of the pons Varolii (Fig. 388, p. 482). The area thus constituted is lozenge-shaped, its widest part being opposite the upper ends of the restiform bodies or inferior peduncles of the cerebellum. A thick layer of gray matter, continuous with that which surrounds the central canal of the cord, is spread out like a carpet over the ventricular floor, and covering this is the usual ependymal layer, which lines all the ventricles of the brain. The area is circumscribed by definite lateral boundaries.

Thus, *below* it is bounded on either side by the clava, the cuneate tubercle, and the restiform body; whilst *above* the lateral limits are formed by the superior cerebellar peduncles.

The floor of the fourth ventricle is divided into two lateral and symmetrical portions by a median groove. Its lower narrow pointed portion between the two clavæ receives the name of the **calamus scriptorius**, from its fancied resemblance to the point of a pen. Crossing each half of the floor, at its widest part, are several more or less conspicuous bundles of fibres termed the **striæ acusticæ**. They appear to emerge from the mesial groove and they are carried outwards over the floor of the ventricle in the region between its upper pontine and lower medullary portions. The striæ acusticæ exhibit a large amount of variation in different individuals both in their degree of prominence and also in the direction which they pursue. As a general rule they proceed towards the upper part of the restiform body, where they are connected with the cochlear nuclei. Except for this break on the surface, the medullary and pontine portions of the floor of the fourth ventricle are quite continuous with each other.

On the lower medullary district of the ventricular floor a small triangular depression, placed immediately below the striæ acusticæ, catches the eye. This is termed the **fovea inferior.** It is shaped somewhat like an arrow-head. The apex or point looks towards the striæ, whilst the lateral angles of the base are prolonged downwards in the form of diverging grooves (Fig. 391, p. 487). Of these, the inner groove runs towards the opening of the central canal at the calamus scriptorius, whilst the outer groove runs towards the lateral boundary of the floor. In this manner the portion of the floor which lies below the striæ acusticæ is mapped out into three triangular areas. The mesial subdivision is slightly elevated and is termed the **trigonum hypoglossi,** because subjacent to the inner part of this area is the nucleus of origin of the hypoglossal or twelfth cranial nerve. The intermediate area between the two diverging grooves which proceed from the base of the fovea inferior is the **trigonum vagi** (ala cinerea), so called because the nucleus of the vagus or tenth and the glosso-pharyngeal or ninth cranial nerves lies subjacent to it. The external area is the **trigonum acustici.** The base of this area is directed upwards and runs continuously into an eminence—the **acustic area** (area acustica)—over which the striæ acusticæ pass. Subjacent to this district of the floor of the ventricle lies the large terminal chief nucleus of the vestibular division of the auditory or eighth cranial nerve.

A close inspection of the medullary part of the floor of the fourth ventricle in the region of the calamus scriptorius will show that the base of the trigonum vagi is separated from the inner margin of the clava by a narrow lanceolate strip of the ventricular floor, to which Retzius has given the name of **area postrema.** Beneath this area is some vascular tissue (Streeter), and marking it off on its upper and inner aspect from the base of the trigonum vagi there is a translucent cord-like ridge called the **funiculus separans.**

When the floor of the ventricle is examined under water with a magnifying glass, the trigonum hypoglossi is seen to consist of a narrow inner strip which corresponds to the hypoglossal nucleus, and a wider lateral part which has been shown to be the surface representation of another nucleus termed the nucleus intercalatus (Streeter).

On the part of the floor of the ventricle which lies above the striæ acusticæ, and which corresponds to the dorsal surface of the pons, there is also a slight depression termed the **fovea superior.** Between it and the median groove is a marked prominence called the **eminentia teres.** Inferiorly this elevation passes downwards and becomes continuous with the trigonum hypoglossi, whilst above it is carried upwards towards the opening of the aqueduct of Sylvius. In both directions it becomes gradually less prominent, but still it forms a distinct elongated elevation, which stretches along the whole length of the median groove. As already stated, the **area acustica** extends upwards into the pontine part of the ventricular floor and forms an elevated region in the outermost part of its widest portion, below and to the outer side of the fovea superior. Proceeding upwards from the fovea superior to the opening of the Sylvian aqueduct there is a shallow depression termed the **locus cæruleus,** seeing that it usually presents a faint slate-gray colour. When the ependyma is scraped away from the surface of this part of the floor, the colour is seen to be due to the **substantia ferruginea,**—a name applied to a linear group of

strongly pigmented cells, which lies in the lateral part of the gray matter covering this portion of the ventricular floor. When transverse sections are made through the upper part of the pons, the substantia ferruginea appears on the cut surface as a small black spot or dot.

INTERNAL STRUCTURE OF THE MEDULLA.

The internal structure of the medulla differs in a marked degree from that of the spinal cord; indeed, in its upper part it presents very little in common with the latter. The various strands of the cord either come to an end within the medulla or undergo changes in their relative position, whilst the gray matter is much modified and new masses are added. Like the cord, however, the medulla consists of two nearly symmetrical right and left halves. When transverse sections are made through it at different levels each lateral half is seen to be partly marked off from the other in the lower closed part of the medulla by the anterior and posterior median fissures, whilst in the upper open part of the medulla the subdivision is rendered evident in transverse sections by the presence of a distinct median

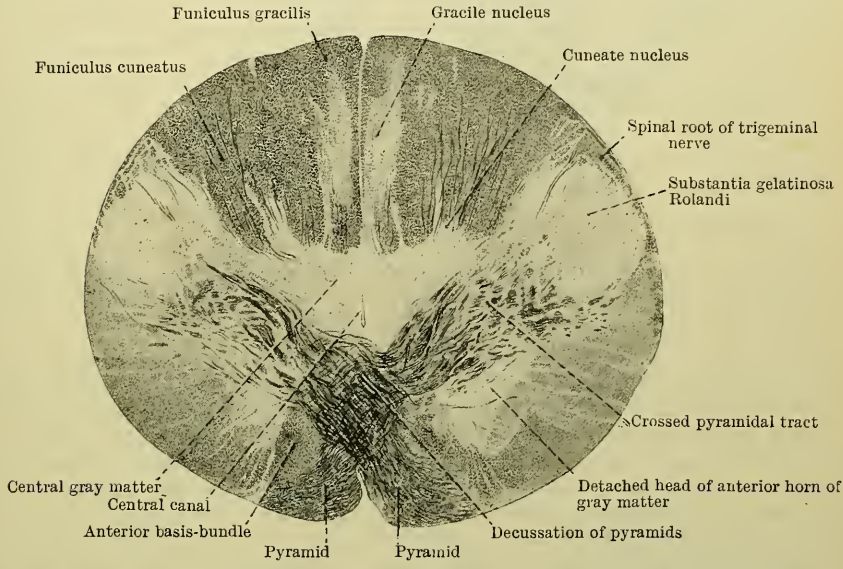


FIG. 392.—SECTION THROUGH THE LOWER END OF THE MEDULLA OBLONGATA OF A CHIMPANZEE TO SHOW THE DECUSSATION OF THE PYRAMIDS.

line, called the **raphe**, which occupies the mesial plane. The raphe is formed by the close intersection of fibres running in different directions and crossing from one side to the other.

Each half of the medulla is composed of: (*a*) strands of white matter; (*b*) gray matter; and (*c*) the formatio reticularis.

The **white matter**, as in the cord, is to a large extent disposed on the surface, and the gray matter in the interior; but in the upper open part of the medulla the gray matter comes to the surface on the dorsal aspect, and is spread out over that area which forms the medullary part of the floor of the fourth ventricle. In the cord the white matter, in the shape of massive longitudinal strands of fibres, forms a thick coating round the central gray matter. In the medulla the only massive longitudinal strands which are seen on the surface are the gracile and cuneate strands (until they become absorbed by the subjacent nuclei), the inferior cerebellar peduncles or restiform bodies and the pyramidal tracts. Elsewhere the coating of white matter is thin, and in certain places is composed chiefly of the superficial arcuate fibres. New longitudinal strands, however, take shape within the medulla, and two of the most important are placed on either side of the median raphe.

The **gray matter** of the cord, as it is continued upwards into the medulla,

becomes greatly modified. A considerable part of it is broken up in the formatio reticularis, whilst the only portions which remain as compact masses in direct continuity with the gray matter of the cord are: (1) the thick layer which surrounds the central canal, and which, in the open part of the medulla, becomes spread out on the floor of the fourth ventricle; and (2) the substantia gelatinosa Rolandi. New masses of gray matter, which are not represented in the cord, and which in some cases appear in isolated clumps, are also added. The chief of these are the gracile and cuneate nuclei, the inferior olivary nuclei, and the arcuate or pyramidal nuclei.

The **formatio reticularis** is only feebly represented in the cord, but in the medulla it forms a very considerable part of its bulk. It is composed of gray matter coarsely broken up by fibres, which traverse it in different directions.

In the following detailed account of the internal structure of the medulla, it must be understood that the appearances described are such as are seen when successive transverse sections through the bulb are examined.

Decussation of the Pyramids and the Changes produced thereby.—As we pass under the microscope a series of successive transverse sections through the upper end of the cord and the lower end of the medulla, the most striking change which meets the eye is the decussation of the pyramids. The crossed pyramidal tract in the lateral column of the cord is seen to become looser in its formation; then coarse strands leave it, pass right through the anterior horn of gray matter, and, crossing the mesial plane, take up their position in the other side of the medulla, close to the antero-median fissure. Strands from the right crossed pyramidal tract alternate with corresponding strands from the left side, and the interval between the bottom of the antero-median furrow and the gray matter surrounding the central canal becomes filled up with a great mass of intercrossing bundles of fibres. When the decussation is completed the pyramid is seen to be composed of a solid and compact bundle of fibres, well marked off from the surrounding structures, which lies at the side of the antero-median fissure of the medulla.

As a rule the inner three-fourths of the pyramid is composed of fibres which, lower down in the opposite lateral column of the cord, form the crossed pyramidal tract, whilst the outer fourth of the pyramid proceeds downwards in the anterior column of the cord of the same side as the direct pyramidal tract. A considerable amount of variation, however, occurs in the proportion of fibres which is allotted to the formation of these two tracts of the cord. Sometimes the crossed pyramidal tract is much larger than usual, and then the direct pyramidal tract suffers a corresponding diminution in size. Cases indeed occur in which the entire pyramid enters into the decussation, and in these there is no direct pyramidal tract in the cord. Further, it is not uncommon to meet with variations of an opposite kind which lead to an increase of the direct pyramidal tract at the expense of the crossed tract. In the majority of cases the decussation appears to be symmetrical—the division of the pyramid at the lower end of the medulla being into parts of corresponding size on the two sides; in certain instances, however, the decussation is asymmetrical, and the corresponding pyramidal tracts on opposite sides of the cord are then unequal in size. Seeing that the direct pyramidal tracts undergo a gradual decussation in the anterior commissure, as they descend in the cord, the final result is the same, no matter what variations occur in the decussation at the lower part of the medulla.

The variations indicated above receive an additional interest when viewed in the light of comparative anatomy. It would appear that only in man and the anthropoid apes is the decussation of the pyramids in the lower part of the medulla incomplete. According to Sherrington, a direct pyramidal tract in the cord of the anthropoid apes stands in connexion with the arm-centre in the cerebral cortex. If this be the case in man it must likewise have other connexions as well, seeing that it is carried down the cord for a considerable distance beyond the level of the cord-segments which give motor fibres to the arm. In the lower apes a direct pyramidal tract does not seem to exist: the whole pyramid crosses over to the opposite side of the cord in the shape of the crossed pyramidal tract.

As we have noted, the decussating pyramidal bundles pass through the anterior horn of gray matter of the cord, and cut it into two portions (Figs. 392 and 395). The basal part remains in position on the anterior and lateral aspect of the central canal, and forms part of the thick layer of gray matter which surrounds it. The

detached head of the anterior horn is set free; and from the large multipolar cells which lie in its midst some of the fibres of the anterior root of the first cervical nerve, and also some of the root fibres of the spinal accessory nerve, take origin.

On proceeding up into the medulla another effect of the decussation of the pyramids is seen in the submergence from the surface of the strand of fibres which, in the anterior column of the cord, lies to the outer side of the direct pyramidal tract, and which receives the name of the anterior basis-bundle. While the decussation is going on the anterior basis-bundle is thrust aside, and, sinking from the surface, it takes up its position as a flattened band-like strand on the outer side of the gradually increasing pyramid (Fig. 393). When the decussation is completed, this strand is seen to lie close to the median plane on the dorsal aspect of the pyramid, where it is separated from its fellow of the opposite side by the median raphe alone (Fig. 394). In the upper part of the medulla it approaches still nearer to the dorsal surface and appears to form the greater part of a strand, which is termed the **posterior longitudinal bundle** (Figs. 397 and 398). The detached head of the anterior horn of gray matter of the cord, as it is traced upwards, is observed to cling closely to its original relationship with the anterior basis-bundle. It is applied to the outer side of this strand, and, gradually becoming smaller, finally disappears at the level of the lower part of the inferior olivary nucleus.

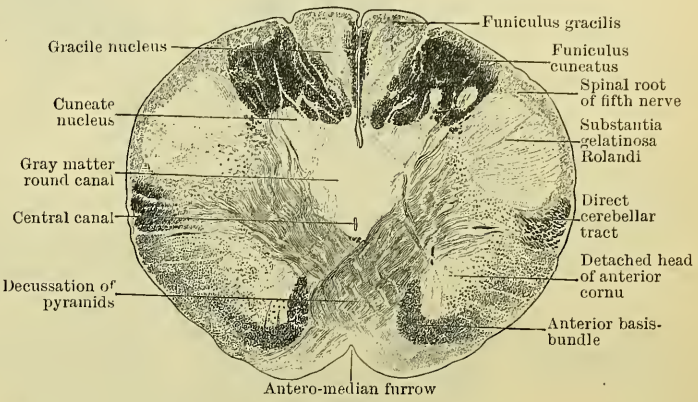


FIG. 393.—TRANSVERSE SECTION THROUGH LOWER END OF THE MEDULLA OF A FULL-TIME FŒTUS,

Treated by the Weigert-Pal method. The gray matter is bleached white, and the medullated tracts of fibres are black.

Cuneate and Gracile Strands, with their Nuclei.—As the funiculus gracilis and the funiculus cuneatus of the posterior column of the cord are traced up into the medulla they seem to increase in bulk, and in transverse sections they assume the form of massive wedge-shaped strands, quite distinct from each other. When the decussation of the pyramids is fully established they change their shape. They increase in width and lose considerably in depth, and consequently the transverse diameter of the area which they occupy becomes greater. As a result of this, and also owing to the removal of the crossed pyramidal tract from the lateral region of the cord immediately in front, the posterior horn of gray matter is gradually rotated forwards and comes to lie transversely and in the same straight line with its fellow of the opposite side (Figs. 393 and 395). The substantia gelatinosa Rolandi, at the same time, becomes increased in quantity and presents a horseshoe-shaped outline in transverse section. It clasps within its concavity the somewhat reduced head of the posterior horn, and forms with it a conspicuous circular mass of gray matter which lies close to the surface, and produces upon it the bulging termed the funiculus and tubercle of Rolando. The basal portion of the posterior horn of gray matter remains upon the dorsal and lateral aspect of the central canal, and forms a portion of the central gray mass of the closed part of the medulla; but very soon the neck of the horn, which at this level is greatly reduced owing to the absence of entering posterior nerve-roots, is invaded by bundles of fibres which traverse it in different directions and convert it into a formatio reticularis. By this means the rounded head of the posterior horn becomes cut off from the central gray matter, and from this point upwards it remains as an isolated gray column intimately associated with the spinal root of the trigeminal nerve.

The **gracile** and **cuneate nuclei** take shape before the decussation of the pyramids is fully completed (Fig. 395). The **gracile nucleus** appears in the form of a small irregular mass of gray matter in the interior of the funiculus gracilis, which

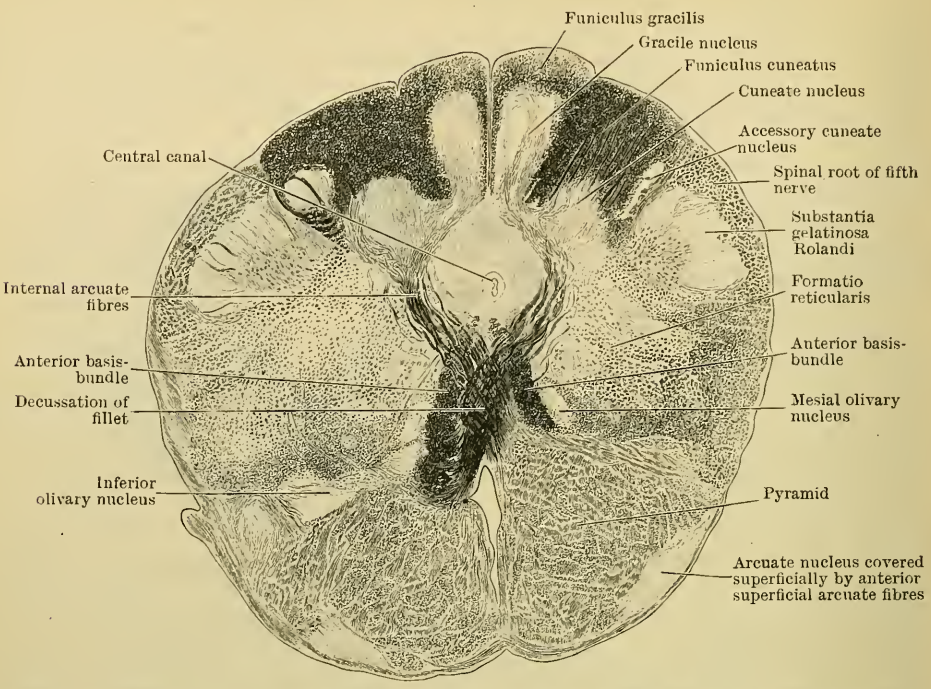


FIG. 394.—SECTION THROUGH THE CLOSED PART OF HUMAN MEDULLA IMMEDIATELY ABOVE THE DECUSSATION OF THE PYRAMIDS (Weigert-Pal Specimen).

gradually infiltrates the entire strand. At first it is not directly connected with the gray matter which surrounds the central canal; but as it is traced upwards it increases in bulk, absorbs more of the strand in which it lies, and such a connexion becomes established (Figs. 393 and 394).

The **cuneate nucleus**, from the first, is a direct offshoot from that part of the base of the posterior horn of gray matter which is preserved as a portion of the central gray mass. In transverse section it is seen to invade the funiculus cuneatus upon its deep aspect, and it gradually grows backwards into its substance. It presents a very different appearance from the gracile nucleus, because throughout its whole length the gray nucleus and the fibres of the strand are separated from each other by a sharp line of demarcation. A second and much smaller mass of gray matter appears in the funiculus cuneatus, superficial to the main nucleus, soon after the region of the decussation of the pyramids is left. This is termed the **accessory** or the **external cuneate nucleus** (Fig. 394).

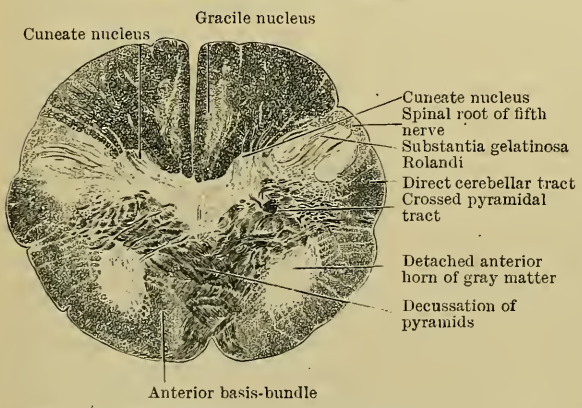


FIG. 395.—SECTION THROUGH THE LOWER PART OF THE MEDULLA OF THE ORANG.

Gradually the fibres of the gracile and cuneate strands become absorbed in these nuclei. As the gray masses gain in size a corresponding diminution in the number of fibres composing the corresponding tracts is observed, until, at the level of the clava and cuneate tubercles, it is seen that these eminences are composed almost

entirely of the gray nuclei, covered by a thin skin of the few remaining fibres of the two strands involved. It would appear that no fibres belonging to the funiculus gracilis and funiculus cuneatus get beyond these nuclei. They all end in fine terminal ramifications around the cells of the nuclei. In the case of the funiculus cuneatus the bundles of fibres, as they pass from the surface into the subjacent gray nucleus, are very distinctly seen in transverse sections through the medulla.

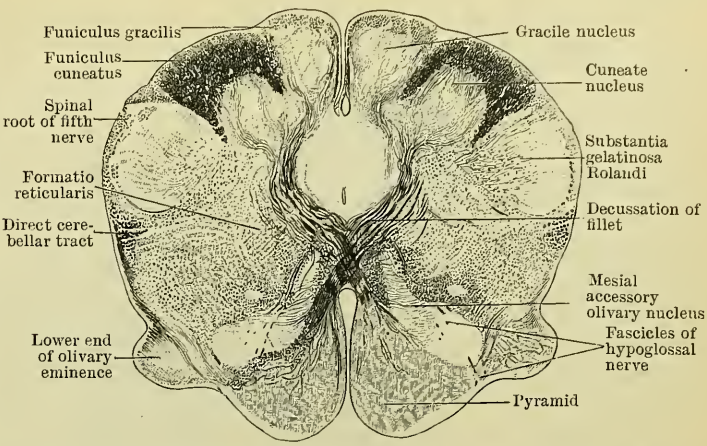


Fig. 396.—Transverse Section through the Closed Part of a Fœtal Medulla, immediately above the Decussation of the Pyramids.

Treated by Weigert-Pal method.

When the medulla oblongata opens up into the fourth ventricle the gracile and cuneate nuclei are pushed outwards by the expanding ventricular floor, and the gracile nucleus soon comes to an end; but the cuneate nucleus extends upwards for a short distance farther, and only terminates when the restiform body begins to take definite shape on its outer aspect.

Decussation of the Fillet (decussatio lemniscorum).—Immediately above the level of the decussation of the pyramids another decussation of fibres in the median plane, and upon the dorsal aspect of the pyramids, takes place in the substance of the medulla. This is termed the **decussation of the fillet**, or the **sensory decussation**, in contradistinction to the term "motor decussation," which is sometimes applied to the decussation of the pyramids. The fibres which take part in this decussation are called **deep arcuate fibres** (fibræ arcuatæ internæ), and they are derived from the cells of the gracile and cuneate nuclei. From the deep aspects of these nuclei these fibres stream forwards and inwards towards the median raphe, forming a series of concentric curves in the substance of the medulla. They cross the mesial plane and decussate with the corresponding fibres of the opposite side, upon the dorsal aspect of the pyramids. Having thus gained the opposite side of the medulla they

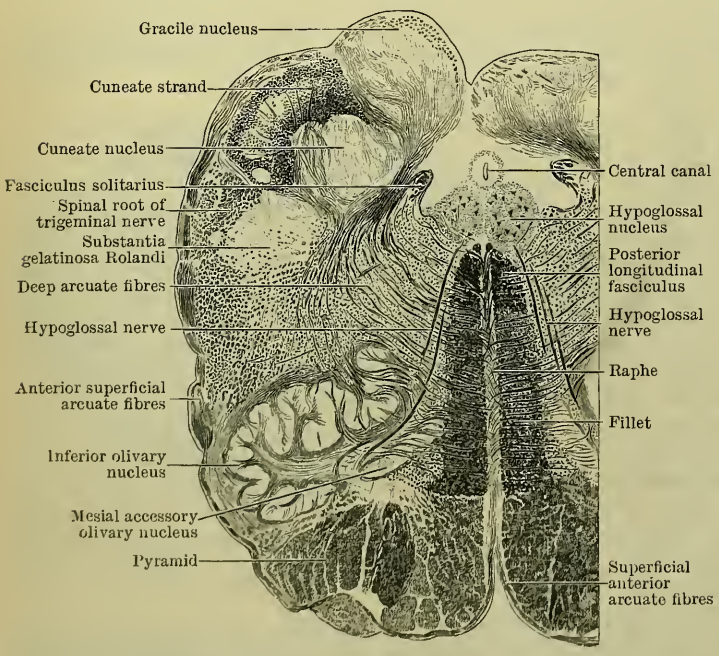


Fig. 397.—Transverse Section through the Human Medulla in the Lower Olivary Region.

immediately turn upwards and form a conspicuous strand of longitudinal fibres, which ascends close to the mesial plane and is separated from its fellow of the opposite side by the median raphe alone. This strand is termed the **fillet** or **lemniscus.**

As we proceed up the medulla the deep arcuate fibres which first come into sight appear as coarse bundles which curve forwards in a narrow group around the central gray matter (Figs. 394 and 396). Soon other finer bundles appear, which describe wider curves on the outer side of the coarser group until a very large part of each lateral half of the medulla is seen to be traversed by these arcuate fasciculi (Fig. 397). As they approach the mesial plane they come in contact with the remains of the anterior basis-bundle, which at this level, as already mentioned, lies upon the dorsal aspect of the pyramid, flattened up against the raphe. The deep arcuate fibres pierce the anterior basis-bundle obliquely, and in the interval between it and the corresponding strand of the opposite side they decussate in the middle line with the deep arcuate fibres of the opposite side. They then change their direction and turn upwards, and the fillet, as already stated, takes form and gradually increases in volume as it ascends. This great and important tract is thus laid down between the pyramid and the anterior basis-bundle; and the consequence of this is that the latter tract is pushed still farther backwards, and, when the fillet is fully established, it comes to lie immediately beneath the gray matter of the floor of the fourth ventricle (Fig. 398).

It is important that we should realise at this stage the full significance of the decussation of the fillet and have a clear conception of the connexions of the fibres which take part in it. The columns of Burdach and Goll, which end in the cuneate and gracile nuclei, are derived from the posterior roots of the spinal nerves. The fillet fibres therefore carry on the continuity of the posterior columns of the cord, the gracile and cuneate nuclei, which are thrown across their path in the lower part of the medulla, merely constituting an internodal interruption. At this point the fillet strand is transferred to the opposite side of the medulla. But it will be remembered that a large proportion of the fibres of the entering posterior nerve-roots of the spinal nerves end in connexion with the cells of the posterior horn of gray matter of the cord. It must not be supposed that the path represented by these latter fibres comes to a termination thereby; from these posterior horn cells other fibres arise which cross to the opposite side of the cord in the anterior white commissure and proceed up the cord to the lateral part of the medulla. These fibres constitute the **spino-thalamic tract** already referred to. The practical bearing of this is that owing to the crossing of the fillet and lower down of the spino-thalamic tract unilateral lesions of the medulla are apt to produce complete hemi-anæsthesia; whilst unilateral lesions of the cord produce only partial hemi-anæsthesia.

When the fillet is fully formed three longitudinal strands are observed traversing the medulla, close to the mesial plane. From before backwards these are: (1) the pyramid, (2) the fillet, and (3) the posterior longitudinal bundle.

The pyramid forms a massive tract in front of and quite distinct from the fillet. The fillet and the posterior longitudinal bundle are, in the first instance, not marked off from each other. They appear as a broad flattened band applied to the raphe. One edge of this band is directed backwards and reaches the gray matter on the floor of the fourth ventricle, while the other edge looks forwards, and is in contact with the pyramid. In the upper part of the medulla the fillet and the posterior longitudinal fasciculus begin to draw asunder from each other. The intermediate longitudinal fibres become reduced in number and the two strands grow denser—the one on the dorsal aspect of pyramid, and the other immediately beneath the gray matter of the floor of the fourth ventricle (Fig. 398).

The **posterior longitudinal bundle** (fasciculus longitudinalis medialis) is thus largely formed out of fibres, which in the cord constitute the anterior basis-bundle. These fibres are thrust back by the two decussations: the first decussation pushing them behind the pyramids, and the second decussation displacing them still farther backwards to a position behind the fillet.

Olivary Nuclei.—The most conspicuous of the isolated clumps of gray matter in the medulla are the inferior olivary nucleus and the two accessory olivary nuclei. The **inferior olivary nucleus** (nucleus olivaris inferior) lies subjacent to the olivary eminence, and constitutes a very striking object in transverse sections through this region. It presents the appearance of a thick wavy or undulating line of gray matter, folded on itself, so as to enclose a space filled with white matter. It is in reality a crumpled lamina arranged in a purse-like manner, with an open

mouth or slit, which is called the **hilum** (hilum nuclei olivaris). directed towards the mesial plane. The hilum does not reach either extremity, so that in transverse

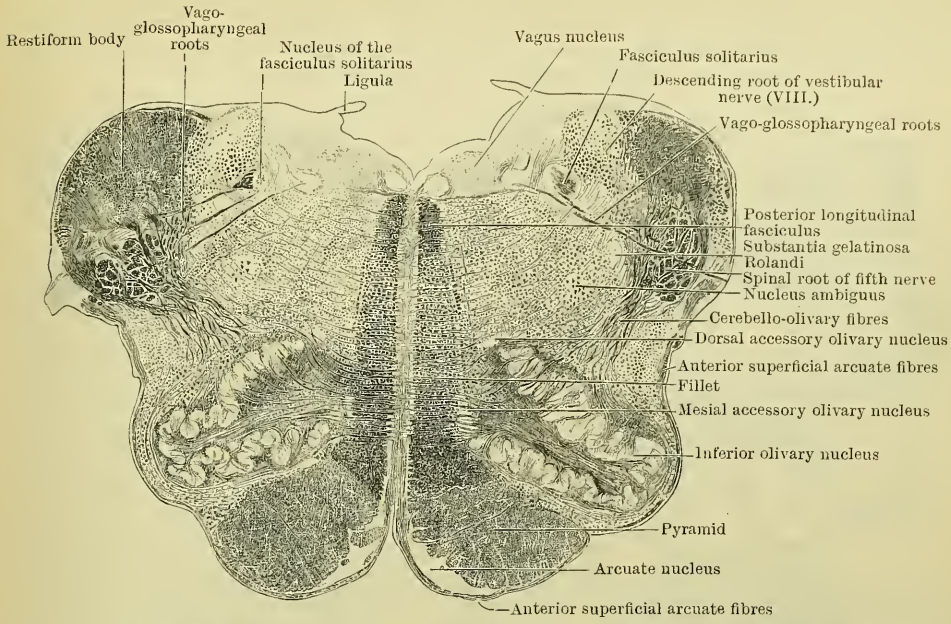


FIG. 398.—TRANSVERSE SECTION THROUGH THE MIDDLE OF THE OLIVARY REGION OF THE HUMAN MEDULLA OR BULB.

The floor of the fourth ventricle is seen, and it will be noticed that the restiform body on each side has now taken definite shape.

sections through each end of the nucleus the gray lamina is seen in the form of a completely closed capsule. Into and out of the open mouth of the olivary capsule streams a dense crowd of fibres. These constitute what is called the **olivary peduncle.**

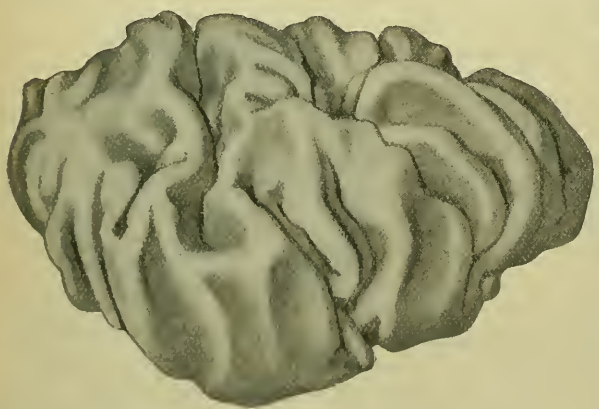


FIG. 399.—THE INFERIOR OLIVARY NUCLEUS, as reconstructed and figured by Miss Florence R. Sabin.

View of the dorso-lateral and lateral surfaces.

The **accessory olivary nuclei** are two band-like laminæ of gray matter, which are respectively placed on the dorsal and mesial aspects of the main nucleus. In transverse section each of these nuclei presents a rod-like appearance (Fig. 398).

The **mesial accessory olivary nucleus** (nucleus olivaris accessorius mesialis) extends lower down in the medulla than the main nucleus, and it is much larger in its lower than its upper part. It begins immediately above the decussation of the pyramids, where it is seen lying on the outer side of the pyramidal tract and the anterior basis-bundle (Figs. 394 and 396). Higher up it lies across the mouth of the main nucleus and on the outer side of the fillet The **dorsal accessory olivary nucleus** (nucleus olivaris accessorius dorsalis) is placed close to the dorsal aspect of the main nucleus. The two accessory nuclei fuse together before they finally disappear.

The gray matter forming the three inferior olivary nuclei consists of a close feltwork of neuroglia in which are interspersed numerous small round cells, each of which is provided with one axon and numerous dendrites. It is traversed by fibres, some of which

pass straight through the gray lamina, whilst others end in connexion with the cells. It is only in man and the higher apes that the inferior olivary nuclei are found strongly developed. In other mammals they are much smaller. The size of the olive appears to be correlated with that of the lateral hemisphere of the cerebellum and not in any way to be dependent on the development of the cerebral hemisphere. Thus in cetacea with a very extensive cerebral cortex the inferior olivary nuclei are small (Edinger).

As the fibres of the fillet decussate and assume a longitudinal direction they come to lie between the olivary nuclei of opposite sides, and hence the term **inter-olivary stratum** (stratum interolivare lemnisci) is frequently applied to them.

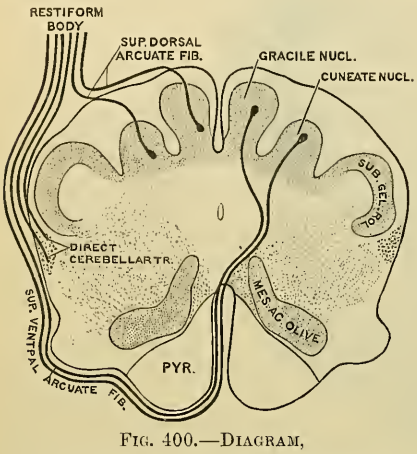


FIG. 400.—DIAGRAM,
Which shows in part the fibres which enter into the constitution of the restiform body.

Restiform Body (corpus restiforme).—The gracile and cuneate nuclei gradually give place to the restiform body in the upper part of the posterior district of the medulla. Fibres from various quarters converge to form this great strand. It first takes shape as a thin superficial layer of longitudinal fibres, which are gathered together on the outside of the cuneate nucleus; but after that nucleus has come to an end, and as the upper part of the medulla is reached, the restiform body is seen to have grown into a massive strand, which presents a kidney-shaped or oval outline on transverse section (Fig. 398), and which ultimately enters the white central core of the cerebellum as its inferior peduncle. The fibres which build up the restiform body are the following: (1) the direct cerebellar tract; (2) the posterior superficial arcuate fibres; (3) the anterior superficial arcuate fibres; and (4) cerebello-olivary fibres.

The **direct cerebellar tract** extends upwards from the lateral column of the cord. In the lateral district of the medulla it occupies a similar position; but before the olivary eminence is reached it inclines backwards, crosses the postero-lateral furrow and passes obliquely upwards into the restiform body. As its fibres diverge, backwards they pass over the tubercule of Rolando and cover up the spinal root of the trigeminal nerve and the substantia Rolandi, thus shutting them out from the surface. The fibres of the direct cerebellar tract in the first instance enter into the outer or superficial part of the restiform body.

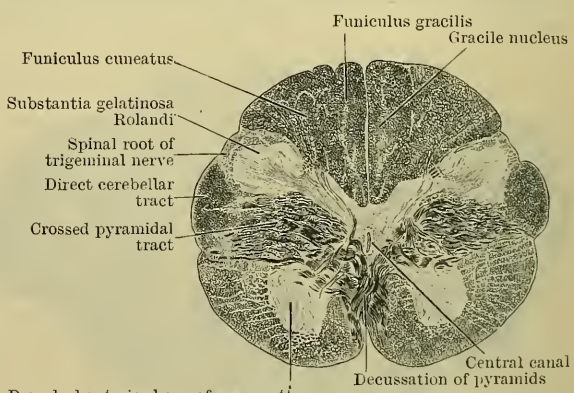


FIG. 401.—SECTION THROUGH THE JUNCTION BETWEEN THE CORD AND MEDULLA OF THE ORANG.
The direct cerebellar tract is well seen, especially on the right side.

Bruce has shown that the fibres of the direct cerebellar tract ultimately lie in the centre of the restiform body, forming as it were its central core, and that in the cerebellum they can be traced to the superior vermis.

The **posterior superficial arcuate fibres** take origin from the gracile and cuneate nuclei, and enter the superficial part of the restiform body of the same side.

The **anterior superficial arcuate fibres** proceed from the lower portions of the gracile and cuneate nuclei of the opposite side. After decussating in the middle line, it can easily be determined that all the deep arcuate fibres which arise from these nuclei do not enter the fillet. A large proportion of them gain the surface by sweeping round the inner aspect of the pyramid in the antero-mesial fissure. Many

of them likewise gain the surface by piercing the pyramid or by passing out between it and the olive. These fibres constitute the anterior superficial arcuate group, and on the surface of the medulla they sweep backwards around it, forming a thin layer over the olivary eminence and ultimately reaching the restiform body. The anterior superficial arcuate fibres, as well as the direct cerebellar tract-fibres, cover over the trigeminal spinal root, which thus comes to take up a deeper position in the substance of the medulla (Figs. 397 and 398).

Amongst the fibres which reach the surface of the medulla in this way Kölliker includes fibres from the striæ acusticæ. If this be the case, these fibres connect the cochlear nucleus with the cerebellum, the path being striæ acusticæ, superficial arcuate fibres, and restiform body (*vide* p. 522).

The fibres of the direct cerebellar tract, which come from the cells of the posterior vesicular column of the cord, and the superficial posterior arcuate fibres, which are derived from the cells of the gracile and cuneate nuclei, do not cross the mesial plane, but enter the restiform body of the same side. The anterior superficial arcuate fibres arise from the cells of the cuneate and gracile nuclei, and cross the mesial plane so as to gain the restiform body of the opposite side.

The **cerebello-olivary fibres** are only seen in the upper part of the medulla. They form the deep part of the restiform body and constitute its chief bulk. Streaming

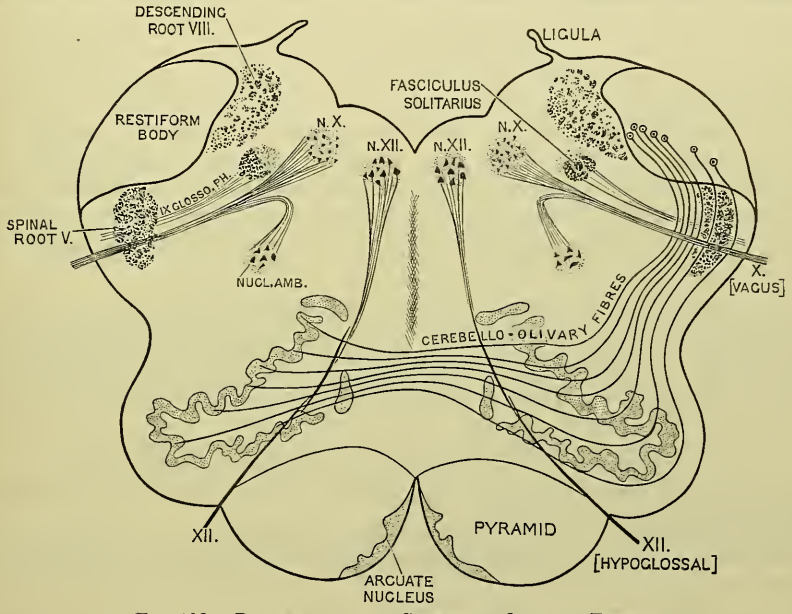


Fig. 402.—Diagram of the Cerebello-Olivary Fibres.

(This diagram has been constructed from the specimen figured on p. 495.)

N.X., Vago-glossopharyngeal nucleus. N.XII., Hypoglossal nucleus.

out from the hilum of the inferior olivary nucleus, they cross the mesial plane, and in the opposite side of the medulla they either pass through the inferior olivary nucleus of that side or sweep around it. Ultimately, on the dorsal aspect of the olivary nucleus, they are gathered together in the form of a conspicuous group of arcuate fibres, which curve backwards to take up a position in the deep part of the restiform body. In passing back, they traverse the spinal root of the trigeminal nerve and break it up into several separate bundles. The cerebello-olivary fibres thus connect the inferior olivary nucleus of one side with the opposite side of the cerebellum.

Although we have traced the cerebello-olivary tract in an upward direction from the olive to the cerebellum, and have thus inferred that it is composed of fibres which proceed from the cells of the inferior olivary nucleus of the opposite side, it is right to state that this view is not universally accepted. There are some who regard these fibres as constituting an efferent tract from the cerebellum, or, in other words, as arising in the cerebellar cortex (probably as the axons of the cells of Purkinje), and descending in the inferior cerebellar peduncle to establish connexions with the cells of the inferior olivary nucleus of the opposite side. If this view be correct, the

destination of the axons of the cells of the inferior olivary nucleus becomes a difficulty, but Kölliker considers that they enter the lateral column of the cord.

Arcuate Nucleus (nucleus arcuatus).—Immediately above the decussation of the pyramids, a small flattened mass of gray matter, covered by superficial arcuate fibres, makes its appearance on the ventral or superficial aspect of the pyramid (Fig. 393). At a higher level when the open part of the medulla is reached, this gray mass shifts its position and comes to lie upon the mesial aspect of the pyramid, and thus constitutes the immediate boundary of the antero-median fissure (Fig. 398). From its intimate connexion with the anterior superficial arcuate fibres, as they sweep out from the antero-median fissure it receives the name of the **arcuate nucleus.**

The nerve-cells which lie in its midst are smaller than those of the inferior olivary nucleus, and are fusiform in shape. It would appear that large numbers of the anterior superficial arcuate fibres end in this nucleus, whilst others take origin within it. Many of the anterior arcuate fibres, however, sweep continuously over its surface and bind it down to the pyramid. At the upper end of the medulla the arcuate nucleus increases in size, and ultimately it becomes continuous with the gray matter of the ventral part of the pons.

Formatio Reticularis.—Behind the olive and the pyramid is the formatio reticularis. In the medulla it occupies a position which, to a large extent, corresponds with that of the lateral column in the spinal cord. In transverse section it appears as an extensive area, which is divided into a lateral and a mesial field by the root fascicles of the hypoglossal nerve as they traverse the substance of the medulla to reach the surface. In the lateral portion which lies behind the olive there is a considerable quantity of gray matter, continuous with that in the cord, present in the reticular formation; it is, therefore, called the **formatio reticularis grisea.** In the mesial part which lies behind the pyramid the gray matter is extremely scanty, and the reticular matter here is termed the **formatio reticularis alba.**

In the **formatio grisea** many of the cells which are scattered thickly amongst the intersecting bundles of fibres are to be regarded as association cells. They possess short axons, which serve to bind different levels of the medulla to each other, and therefore constitute association fibres. Probably the combined and harmonious activity exhibited by the nuclei of the vagus, facial and phrenic nerves in the process of respiration, is attained through the nuclear connexions established by these fibres (Edinger). Certain compact masses of gray matter are also seen in the formatio grisea. Of these may be mentioned *a* the dorsal accessory olivary nucleus, which has been already described, and *b* the nucleus lateralis. The **nucleus lateralis** is seen in the region between the olive and the substantia gelatinosa Rolandi. In the upper part of the medulla it gradually becomes diffuse and disappears.

Except in the immediate vicinity of the raphe, the **formatio alba** may be said to be devoid of cells. The mesial accessory olive, however, forms an isolated compact mass of gray matter within its limits.

The nerve fibres which traverse the formatio reticularis run both in a transverse and a longitudinal direction. The **transverse fibres** are the deep arcuate fibres. The **longitudinal fibres** are derived from different sources in the two fields. In the formatio grisea they represent to a large extent the fibres of the lateral column of the cord, after the removal of the direct cerebellar and the crossed pyramidal tracts. They consist, therefore, of the fibres of the tract of Gowers and of fibres corresponding to the lateral basis-bundle of the cord. In the formatio alba the longitudinal fibres are the tract of the fillet and the posterior longitudinal bundle, both of which have already been sufficiently described.

Central Canal and the Gray Matter which surrounds it.—The central canal, as it proceeds upwards through the closed part of the medulla, is gradually forced to assume a more dorsal position, owing to the accumulation of fibres on its ventral aspect. First the decussation of the pyramids, and then the decussation of the fillet, both of which take place in front of the canal, tend to push it backwards; and the formation of the longitudinal strands in which these intercrossings result (viz. the pyramid and the fillet), together with the continuation upwards of the anterior basis-bundle, lead to a great increase in the amount of tissue which separates it from the anterior surface of the medulla. In the closed part of the medulla it is surrounded by a thick layer of gray matter, which is continuous with

the basal portions of the anterior and posterior horns of gray matter in the cord. This central gray matter is sharply defined on each side by the deep arcuate fibres which curve forwards and inwards around it. Finally, the central canal opens on the dorsal aspect of the medulla into the cavity of the fourth ventricle. The central mass of gray matter which surrounds the canal in the closed part of the medulla is now spread out in a thick layer on the floor of the fourth ventricle, and in such a manner that the portion which corresponds to the basal part of the anterior horn of the cord is situated close to the mesial plane, whilst the part which represents the base of the posterior horn occupies a more lateral position. This is important, because the nucleus of origin of the motor hypoglossal nerve is placed in the mesial part of the floor, whilst the nuclei of termination of the afferent fibres of the vagus, glosso-pharyngeal, and auditory nerves lie in the lateral part of the floor. The gray matter of the ventricular floor is covered by ependyma.

Three Areas of Flechsig.—In transverse sections, through the upper open part of the medulla, the root fibres of the hypoglossal and vagus nerves are seen traversing the substance of the medulla. The nucleus of origin of the hypoglossal is placed in the gray matter of the floor of the fourth ventricle close to the mesial plane; the nucleus of the vagus is situated in the gray matter of the ventricular floor immediately to the outer side of the hypoglossal nucleus. From these nuclei the root-bundles of the two nerves diverge from each other as they are traced to the surface and subdivide the substance of the medulla, as seen in transverse section, into the three areas of Flechsig, viz. an anterior, a lateral, and a posterior.

The **anterior area**, which is bounded internally by the median raphe and externally by the hypoglossal roots, presents within its limits: (*a*) the formatio alba; (*b*) the pyramid; (*c*) the fillet; (*d*) the posterior longitudinal fasciculus; (*e*) the mesial accessory olivary nucleus; (*f*) the arcuate nucleus.

The **lateral area** lies between the root fibres of the hypoglossal and those of the vagus. It contains: (*a*) the inferior olivary nucleus; (*b*) the dorsal accessory olivary nucleus; (*c*) the nucleus lateralis; (*d*) the nucleus ambiguus, or the motor nucleus of the vagus and glosso-pharyngeal nerves; (*e*) the formatio reticularis grisea.

The **posterior area** is situated behind the vagus roots, and within its limits are seen: (1) the restiform body; (2) the upper part of the cuneate nucleus; (3) to the inner side of this a crowd of transversely-cut bundles of fibres, loosely arranged and forming the descending root of the vestibular part of the auditory nerve; (4) close to these, but placed more deeply, a round, compact, and very conspicuous bundle of transversely-cut fibres, viz. the fasciculus solitarius, or descending root of the vagus and glosso-pharyngeal nerves; (5) the substantia gelatinosa Rolandi, much reduced, with the large spinal root of the trigeminal nerve close to its outer side.

INTERNAL STRUCTURE OF THE PONS VAROLII.

When transverse sections are made through the pons, it is seen to be composed of a ventral part and a dorsal or tegmental part. The **ventral part** is much the larger of the two, and, broadly speaking, it corresponds to the pyramidal portions of the medulla and the pedal portions of the two crura cerebri, which lie above it and appear to issue from it. The dorsal **tegmental part** may be regarded as the continuation upwards of the formatio reticularis grisea and the formatio reticularis alba. As these parts are traced upwards into the pons they become much modified, and new constituents are added.

Ventral Part of the Pons (pars basilaris pontis).—This constitutes the chief bulk of the pons. It is composed of: (1) transverse fibres arranged in coarse bundles; (2) longitudinal fibres, gathered together in massive bundles; and (3) a large amount of gray matter, termed the **nucleus pontis**, which fills up the interstices between the intersecting bundles of fibres.

The **longitudinal fibres**, to a large extent, consist of the same fibres which, lower down, are gathered together in the two solid pyramidal tracts of the medulla. When the pyramids are traced upwards they are seen to enter the pons in the form of two compact bundles. Soon, however, they become broken up into smaller bundles by the transverse fibres of the pons, and are spread out over a wider area. At the upper border of the pons they again come together and form two solid strands, each of which is carried into the central part of the corresponding pedal portion of the crus cerebri.

The **transverse fibres** at the lower border of the pons are placed on the superficial or ventral aspect of the pyramidal bundles. As we proceed upwards they increase in number, and many are seen breaking through the pyramids and even

passing across upon the dorsal aspect of the latter. Laterally these transverse fibres are collected together into one compact mass, which enters the white central core of the cerebellum and constitutes the **middle cerebellar peduncle.** At the mesial plane the transverse fibres of the two sides of the ventral portion of the pons intercross and form a coarse decussation.

The **gray matter** (the nucleus pontis) forms a considerable part of the bulk of the ventral portion of the pons. It is packed into the intervals between the intersecting transverse and longitudinal bundles.

There is a close analogy between the pyramidal portions of the medulla and the ventral part of the pons. In the medulla fine arcuate fibres on their way to the surface pass through the pyramids. Other superficial arcuate fibres sweep over the surface of the pyramids. These present a strong resemblance to the transverse fibres of the pons. They likewise reach the cerebellum, although by a different route, viz. the inferior cerebellar peduncle. The nucleus pontis is also represented in the pyramidal part of the medulla by the arcuate

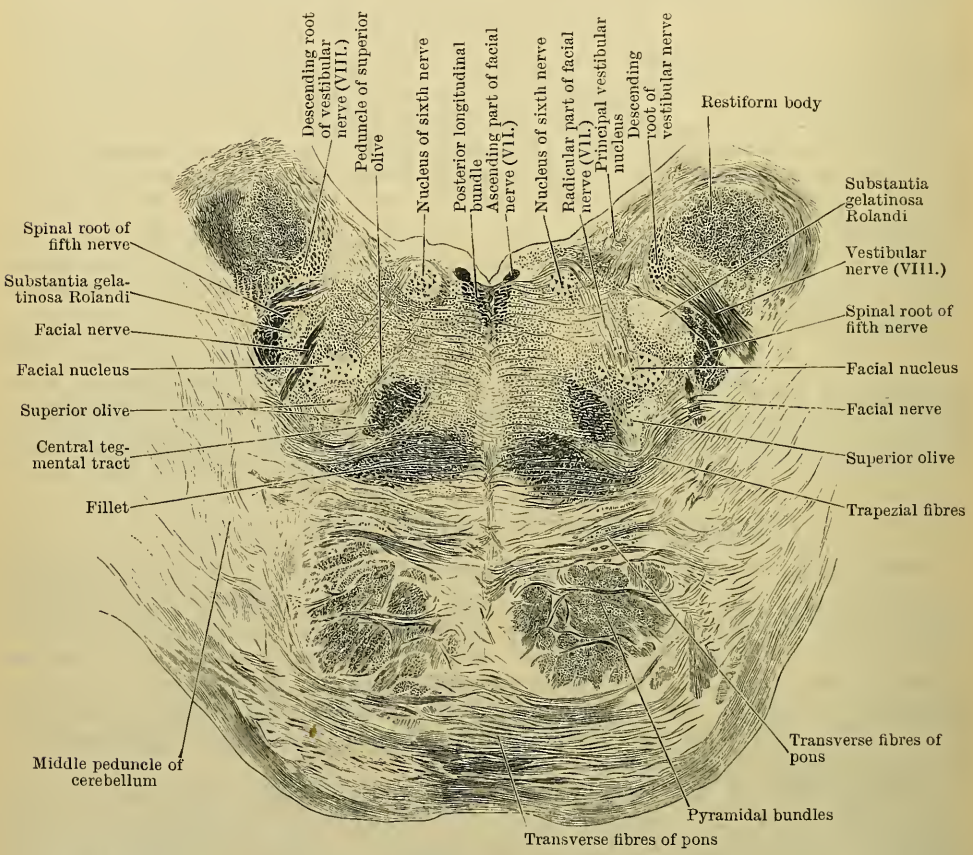


FIG. 403.—SECTION THROUGH THE LOWER PART OF THE HUMAN PONS VAROLII IMMEDIATELY ABOVE THE MEDULLA.

nuclei, which are covered over by the superficial arcuate fibres, and even tend to penetrate, to a slight extent, into the pyramidal tracts. These arcuate nuclei, as already pointed out, are continuous with the nucleus pontis.

Connexions of the Longitudinal and Transverse Fibres.—Our knowledge of the connexions of the longitudinal and transverse fibres of the ventral part of the pons is very far from being complete. When a transverse section through the upper part of the pons is compared with one close to its lower border, it becomes at once apparent that the numerous scattered bundles of longitudinal fibres which enter the ventral part of the pons from above, if brought together into one tract, would form a strand very much larger than the two pyramids which leave its lower aspect and enter the medulla. It is clear, therefore, that many of the longitudinal fibres which pass into the pons from above do not pass

out from it below into the medulla. What becomes of these fibres that are thus absorbed in the pons? It is known that the pyramidal bundles suffer a small loss by the fibres which they send to the nuclei of origin of the efferent nerves which arise within the pons (viz. the motor root of the fifth, the sixth, and seventh nerve nuclei); but this loss is, comparatively speaking, trifling. It is clear, therefore, that other longitudinal bundles enter the pons from above than those which form the pyramidal tracts. These bundles occupy a lateral and dorsal position in the ventral part of the pons, and may be termed the **cortico-pontine fibres**, seeing that they come from the cerebral cortex and end in fine ramifications around the cells of the nucleus pontis.

The transverse fibres are of two kinds, viz.: (1) those which arise in the cortex of the cerebellum; and (2) those which take origin in the nucleus pontis. The former are the axons of certain of the cells of the cortex of the cerebellum (cells of Purkinje). They come chiefly from the lateral hemisphere, but also to some extent from the median lobe of the cerebellum, and enter the pons by the middle peduncle. They end in fine ramifications around the cells of the nucleus pontis, some on the same side as the peduncle through which they reach the pons, but the majority in the gray matter of the opposite side.

The transverse fibres which arise in the pons take origin as axons of the cells of the nucleus pontis. Crossing the mesial plane, they enter the middle peduncle of the opposite side, and thus reach the cerebellar cortex, where they end in ramifications round certain of the cortical cells. The middle peduncle thus contains both efferent and afferent cerebellar fibres, and no fibres pass continuously through the pons from one middle peduncle into the other. In opposition to this view, Klimoff and others hold that the middle peduncle is composed solely of centripetal or afferent fibres, which pass from the nucleus pontis to the cerebellum. Some of these fibres are crossed and others direct.

Certain of the transverse fibres of the pons turn backwards and enter the dorsal or tegmental part of the pons, but the precise connexions of these are doubtful.

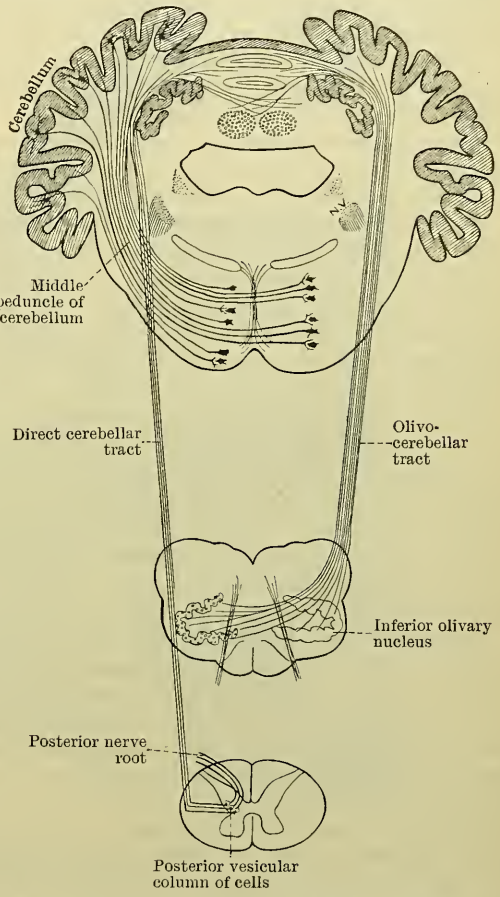


Fig. 404. — Diagram to show connexions of the Direct Cerebellar and the Olivo-Cerebellar Tracts. The connexions of the fibres of the middle peduncle of the cerebellum are likewise diagrammatically shown (from Edinger, modified).

Corpus Trapezoides.—This name is applied to a group of transverse fibres which traverse the lower part of the pons (Fig. 405). They are quite distinct from those which have been just described as entering the middle peduncle of the cerebellum, and they lie in the boundary between the dorsal and ventral parts of the pons, but encroaching considerably into the ground of the former. They arise from the cells of the terminal nucleus of the cochlear division of the auditory nerve, and constitute a tract which establishes certain central connexions for that nerve. They will be more fully described when we treat of the cerebral connexions of the auditory nerve.

Dorsal or Tegmental Part of the Pons (pars dorsalis pontis).—On the dorsal surface of the tegmental part of the pons there is spread a thick layer of gray

matter, covered by ependyma, which forms the floor of the upper or pontine part of the fourth ventricle. Beneath this the mesial raphe of the medulla is continued up into the pons, so as to divide its tegmental part into two symmetrical halves.

In the *lower part of the pons*, immediately beyond the medulla, the restiform body is placed on the outer side of the tegmental part (Fig. 403). In transverse sections through the pons it appears as a large, massive oval strand of fibres which gradually inclines backwards into the cerebellum, and thus leaves the pons. Between the restiform body and the median raphe the tegmental part of the pons is composed of formatio reticularis, continuous with the same material in the medulla. Thus arcuate or transverse fibres, curving in towards the raphe, and also longitudinal fibres, are seen breaking through a mass of gray matter which occupies the interstices of the intersecting fibres. To the naked eye the formatio reticularis presents a uniform gray appearance, but its constituent parts are revealed by low powers of the microscope in properly-stained and prepared specimens. Embedded in this formatio reticularis are various clumps of compact gray matter and certain definite strands of fibres. These we shall describe as we pass from the restiform body inwards towards the median raphe.

(1) **Spinal root of the trigeminal nerve and the substantia gelatinosa Rolandi.**— Close to the inner side of the restiform body, but separated from it by the vestibular root of the auditory nerve as it proceeds backwards through the pons, is seen a large crescentic group of coarse transversely-divided bundles of fibres. This is the spinal root of the fifth nerve, and applied to its inner concave side is a small mass of gray matter, which is the direct continuation upwards of the substantia gelatinosa Rolandi.

(2) The **nucleus of the facial or seventh nerve** comes next. It is sunk deeply in the tegmental part of the pons and lies close to the transverse fibres of the corpus trapezoides. It is a conspicuous, obliquely placed, ovoid clump of gray matter. From its outer and dorsal aspect the root-fibres of the facial nerve stream backwards and inwards towards the gray matter on the floor of the fourth ventricle. Passing forwards between this nucleus and the substantia Rolandi a solid nerve-bundle may be observed. This is the facial nerve, traversing the pons towards its place of emergence from the brain.

(3) Immediately internal to the facial nucleus, but placed more deeply in the tegmental part of the pons, is the **superior olivary nucleus** (nucleus olivaris superior). It lies in a bay formed for it by the transverse fibres of the corpus trapezoides. These fibres curve round its ventral aspect, and many of them may be observed penetrating into its substance. In man it is a very small mass of gray matter, and presents little resemblance to the inferior olivary nucleus, except in the size and shape of its constituent cells. In sections through the part of the pons where it attains its greatest size, it appears in the form of two, or it may be three, small isolated masses of gray matter. It is intimately connected with the trapezial fibres, many of which end in it, whilst others take origin within it.

Upon the inner and dorsal aspect of the superior olive there is a dense group of longitudinal fibres. These constitute the **central tegmental tract**; but as precise information in regard to its connexions is still to a large extent wanting, it is not necessary to do more than indicate its position.

(4) The **posterior longitudinal bundle** and the **fillet** come next. As they proceed upwards through the tegmental part of the pons, these longitudinal tracts occupy the same relative position as in the medulla. They are placed close to the median raphe; but they have drawn further apart from each other, and their fibres are more distinctly concentrated into separate strands, with an interval of some little width between them. The **posterior longitudinal bundle** lies immediately under cover of the gray matter of the floor of the fourth ventricle. The **fillet** is placed close to the trapezial fibres, many of which traverse it as they pass towards the mesial plane.

(5) The **nucleus of the sixth nerve** also forms a conspicuous object in sections through the lower part of the pons. It is a round mass of gray matter, which is situated close to the outer side of the posterior longitudinal bundle, and immediately

under cover of the gray matter of the floor of the fourth ventricle. From its inner side numerous root-bundles of the sixth nerve pass out and proceed forwards beween the fillet and the superior olivary nucleus. They occupy in the pons, therefore, a position similar to that occupied by the hypoglossal root-fibres in the medulla.

Up to the present only the lower part of the tegmental portion of the pons has been described, *i.e.* the portion immediately adjoining the medulla. As we proceed upwards and gain a point *above the level of the trapezial fibres*, many of the structures which have attracted attention lower down gradually disappear from the formatio reticularis. The posterior longitudinal bundle, the fillet, and the spinal root of the fifth nerve, however, are still carried upwards. Further, the

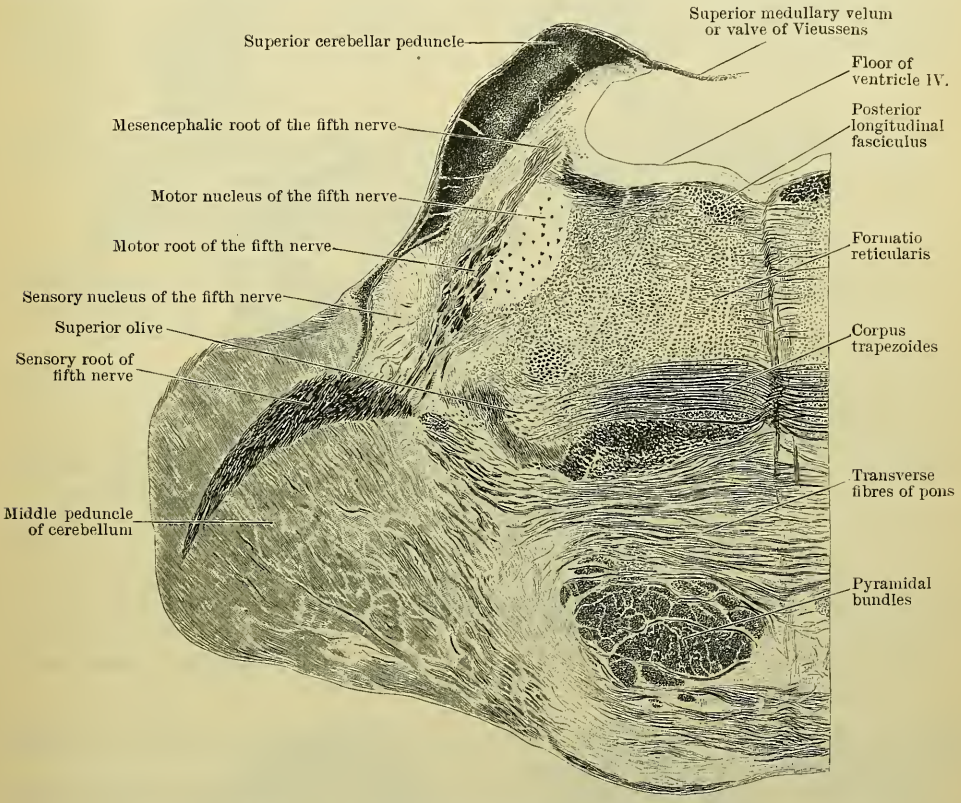


FIG. 405.—TRANSVERSE SECTION THROUGH THE PONS VAROLII AT THE LEVEL OF THE NUCLEI OF THE TRIGEMINAL NERVE (Orang).

floor of the fourth ventricle becomes narrower, and other objects appear in the tegemental substance.

The **superior cerebellar peduncle** (brachium conjunctivum) is a very conspicuous object, in sections, through the middle and upper parts of the pons. In transverse section it presents a semilunar outline, and as it emerges from the cerebellum it lies immediately on the outer side of the fourth ventricle, towards which its concave aspect is turned (Fig. 405). Its dorsal border is joined with the corresponding peduncle of the opposite by the thin lamina of white matter, termed the superior medullary velum, whilst its ventral border is sunk to a small extent in the dorsal part of the pons. As it is traced upwards it sinks deeper and deeper into the pons until it becomes completely submerged, with the exception of the posterior border to which the superior velum is attached. It now lies on the outer side of the tegmental or reticular substance of the pons, and this position it maintains until the mesencephalon is reached (Fig. 406).

About *half-way up the pons* the nuclei of the trigeminal or fifth cranial nerve mark a very important stage in its tegmental portion. These nuclei are two in

number on each side, viz. a large oval terminal nucleus for certain of the sensory fibres of the nerve and a nucleus of origin equally conspicuous for certain of the motor fibres (Fig. 405). The **sensory nucleus** lies close to the outer surface of the pons, deeply sunk in its tegmental part, and in the interval between the submerged anterior border of the superior cerebellar peduncle and the ventral part of the pons. The **motor nucleus** is placed on the inner side of the sensory nucleus, but somewhat nearer the dorsal surface of the pons. At this level the spinal root of the fifth nerve disappears by joining the fibres of the sensory portion. The sensory and motor roots of the fifth nerve traverse the ventral part of the pons on their way to and from the region of the nuclei.

Above the level of the nuclei of the trigeminal nerve a new tract of fibres comes into view. This is the **mesencephalic root** of the fifth nerve, as it descends to join the emerging fibres of the motor part of the fifth nerve. It is a small bundle of nerve fibres, semilunar in cross section, which lies close to the inner side

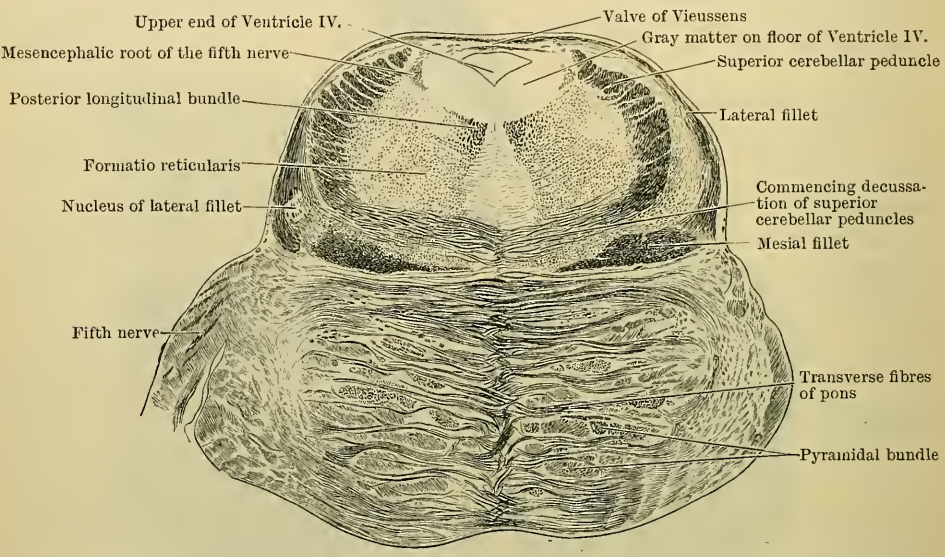


Fig. 406.—Section through the Upper Part of the Pons Varolii of the Orang, above the Level of the Trigeminal Nuclei.

of the superior cerebellar peduncle and on the outer and deep aspect of the gray matter on the floor of the fourth ventricle (Figs. 406 and 407).

On a slightly deeper plane than the mesencephalic root of the fifth nerve, between it and the posterior longitudinal bundle, and in close relation to the gray matter of the floor of the ventricle, is the collection of pigmented cells which constitutes the **substantia ferruginea.**

The **posterior longitudinal bundle,** as it is traced upwards through the tegmental part of the pons, maintains the same position throughout, and as it ascends it becomes more clearly mapped out as a definite and distinct tract. It lies close to the mesial raphe, and immediately subjacent to the gray matter of the floor of the fourth ventricle.

The **fillet** as it ascends through the tegmental part of the pons undergoes striking changes in shape. In the lower portion of the pons its fibres, which in the medulla are spread out along the side of the median raphe, are collected together in the form of a loose bundle, which occupies a wide field, somewhat triangular in shape, on either side of the median raphe and immediately behind the ventral portion of the pons. As it proceeds up, the fibres spread out laterally until a compact ribbon-like layer is formed in the interval between the tegmental and ventral portions of the pons. This constitutes what is termed the **mesial fillet** (Figs. 406 and 407).

Above the level of the trigeminal nuclei another flattened layer of fibres comes

into view to the outer side of the mesial fillet. To this the name of **lateral fillet** is given. These fibres spread outwards and backwards, and finally take up a position on the outer surface of the superior cerebellar peduncle. In the angle between the mesial and lateral fillets a little knot of compact gray matter, termed the **lateral**

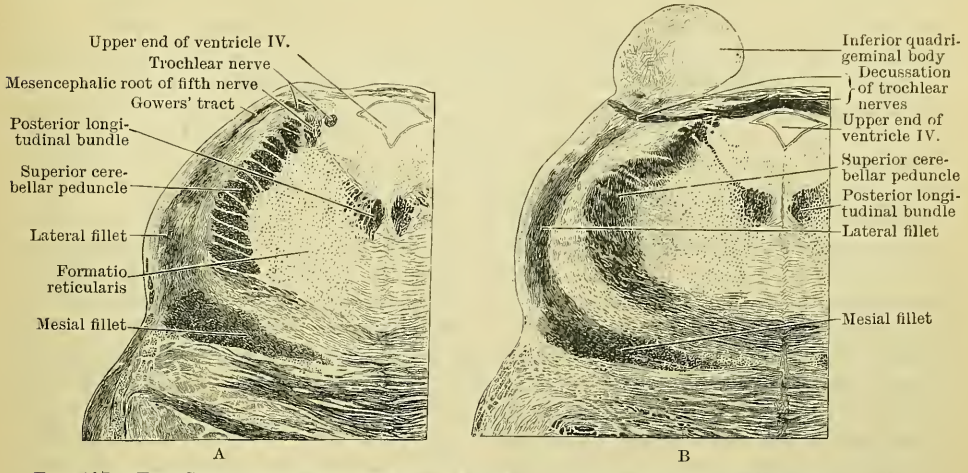


FIG. 407.—TWO SECTIONS THROUGH THE TEGMENTUM OF THE PONS AT ITS UPPER PART, CLOSE TO THE MESENCEPHALON.

A is at a slightly lower level than B.

fillet nucleus, comes into view (Fig. 406). This appears to be in more or less direct continuity with the superior olivary nucleus. Many of the fibres of the lateral fillet take origin in this nucleus. Bruce has called attention to the continuity between the superior olive and the lateral fillet nucleus in man, and the writer can confirm his statement in so far as the orang brain is concerned.

THE CEREBELLUM.

The **cerebellum** lies behind the pons Varolii and the medulla oblongata, and below the hinder portions of the cerebral hemispheres. From the latter it is

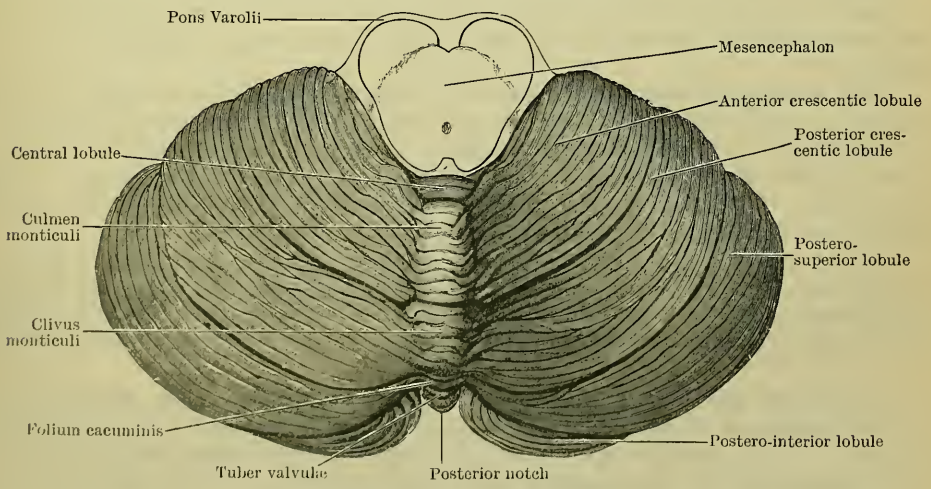


FIG. 408.—UPPER SURFACE OF THE CEREBELLUM.

separated by an intervening partition of dura mater, termed the tentorium cerebelli. It is distinguished by the numerous parallel and more or less curved sulci, which traverse its surface and give it a foliated or laminated appearance. It is composed of a cortex of gray matter (substantia corticalis) spread over its surface, with white matter in the interior, forming a central core (corpus medullare).

The cerebellum is subdivided somewhat arbitrarily into a median portion termed the **vermis**, and two much larger lateral portions, called the **lateral hemispheres** (hemisphæria cerebelli). The demarcation between these main subdivisions of the organ is not very evident from every point of view. In front, and also behind, there is a marked deficiency or notch. The **posterior notch** (incisura cerebelli posterior) is smaller and narrower than the anterior notch. It is bounded laterally by the lateral hemispheres, whilst its bottom is formed by the median lobe or vermis. It is occupied by a fold of dura mater, called the falx cerebelli. The **anterior notch** (incisura cerebelli anterior) is wide, and, when viewed from above, it is seen to be occupied by the inferior quadrigeminal bodies and by the superior peduncles of the cerebellum. As in the case of the hinder notch, its sides are formed by the lateral hemispheres and the bottom by the vermis.

On the superior surface of the cerebellum there is little distinction to be noted between the median lobe and the upper surface of each lateral hemisphere. On this aspect the median lobe receives the name of **superior vermis**, and it forms a high median elevation, from which the surface slopes gradually downwards on each side to the margin of the hemisphere. The superior vermis is highest in front, immediately behind the anterior notch, and from this it shows a somewhat sharp descent towards the posterior notch. This elevation of the superior worm is frequently called the monticulus cerebelli. The folia on the surface of the superior vermis are thicker and fewer in number than those on the upper surface of the lateral hemisphere. It is this which gives it the worm-like appearance from which it derives its name.

On the inferior surface of the cerebellum the distinction between the three main constituent parts of the organ is much better marked (Fig. 409). On this aspect the lateral hemispheres are full, prominent, and convex, and occupy the cerebellar fossæ in the floor of the cranium. They are separated by a deep mesial hollow, which is continued forwards from the posterior notch. This hollow is termed the **vallecula cerebelli**, and in its fore-part is lodged the medulla oblongata. When the medulla is raised and the lateral hemispheres are pulled apart, so as to expose the bottom of the vallecula, it will be seen that this is formed by the **vermis inferior**, or inferior aspect of the median lobe, and, further, that the latter is separated on each side from the corresponding lateral hemisphere by a distinct furrow, termed the **sulcus valleculæ**.

Sulci Cerebelli.—Certain of the fissures which traverse the surface of the cerebellum are deeper and longer than the others, and they map out districts which are termed lobes. One of the most conspicuous of these clefts is the great horizontal fissure.

The **great horizontal fissure** (sulcus horizontalis cerebelli) of the cerebellum begins in front and passes continuously round the circumference of the organ, cutting deeply into its outer and posterior margins. In front, its lips diverge to enclose the three cerebellar peduncles as they pass into the interior of the cerebellum. The great horizontal fissure divides the organ into an upper and a lower part, which may be studied separately.

The prominence which is accorded to the great horizontal fissure in descriptive anatomy is not justified by its developmental history and morphological status. It is very late in making its appearance in the fœtal cerebellum, and not infrequently the part of the fissure on the one side fails to establish a continuity across the vermis with the part of the fissure on the other side of the organ.

Lobes on the Upper Surface of the Cerebellum.—When examined from before backwards, the superior vermis presents the following subdivisions: (1) the **lingula**; (2) the **central lobule** (lobulus centralis); (3) the **culmen monticuli**; (4) the **clivus monticuli**; (5) the **folium cacuminis** (folium vermis). With the exception of the lingula, each of these is continuous on either side, with a corresponding district on the upper surface of the hemisphere, thereby forming a cerebellar lobe. Thus the central lobule is prolonged outwards on either side in the form of a small, flattened, wing-like expansion called the **ala**; the culmen constitutes the median connecting piece between the two **anterior crescentic lobules** of the hemispheres; the clivus stands in the same relation to the two **posterior crescentic lobules**; and

the folium cacuminis is the connecting band between the **postero-superior lobules** of the hemispheres.

It should be noted that this subdivision of the upper surface of the cerebellum is to some extent conventional, and in certain particulars receives little support from morphological data.

The **lingula** can only be seen when the part of the cerebellum which forms the bottom of the anterior notch is pushed backwards. It consists of four or five small flat folia continuous with the gray matter of the vermis superior, which are prolonged forwards on the upper surface of the superior medullary velum in the interval between the two superior cerebellar peduncles.

Lobus Centralis with its Alæ.—The lobulus centralis lies at the bottom of the anterior cerebellar notch, and is only seen to a very small extent on the upper surface of the organ. It is a little median mass which laterally is prolonged outwards for a short distance round the anterior notch in the form of two expansions, termed the alæ.

Lobus Culminis.—The culmen monticuli constitutes the highest part or summit of the monticulus of the vermis superior. It is bounded behind by a deep and strongly marked fissure called the **fissura prima** (Elliot Smith), and is prolonged outwards on either side into the lateral hemisphere as the **anterior crescentic lobule.** This is the most anterior subdivision on the upper surface of the hemisphere. The two anterior crescentic lobules, with the culmen monticuli, form the **lobus culminis cerebelli.**

Lobus Clivi.—The clivus monticuli lies behind the culmen, from which it is separated by the fissura prima, and it forms the sloping part or descent of the monticulus of the vermis superior. On each side it is continuous with the **posterior crescentic lobule** of the lateral hemisphere, and the three parts are included under the one name of **lobus clivi.**

The two crescentic lobules on the upper surface of the hemisphere are sometimes classed together and described as the **lobulus quadrangularis.** They are separated from each other by a lateral extension on the upper surface of the hemisphere of the fissura prima, whilst the posterior crescentic lobule is bounded behind by a curved sulcus termed by Elliot Smith the **fissura postlunata.** The union of the two postlunate furrows across the vermis separates the clivus from the folium cacuminis, but in many cases this junction fails to take place.

Lobus Cacuminis.—The folium cacuminis forms the most posterior part of the vermis superior, and when the right and left portions of the great horizontal fissure are continuous across the vermis it bounds that fissure superiorly at the posterior notch. It is a single folium, subject to considerable variation in the degree of its development, and its surface may be smooth or beset with rudimentary secondary folia. It is the median connecting link between the two **postero-superior lobules** of the hemispheres, the three parts forming the **lobus cacuminis.** As the folium cacuminis is traced outwards into the postero-superior lobule, it is found to expand greatly, and as a result of this the postero-superior lobule on each side forms an extensive foliated district bounding the great horizontal fissure above.

Lobes on the Under Surface of the Cerebellum.—The connexion between the several parts of the inferior vermis and the corresponding districts on the under surface of the two hemispheres is not so distinct as in the case of the vermis superior and the lobules on the upper surface of the hemispheres. A groove, the **sulcus valleculæ,** intervenes between the vermis inferior and the hemisphere on each side.

From behind forwards the following subdivisions of the vermis inferior may be recognised: (1) the **tuber valvulæ** (tuber vermis); (2) the **pyramid** (pyramis); (3) the **uvula**; (4) the **nodule** (nodulus).

On the under surface of the hemisphere there are four main lobules mapped out by intervening fissures. From behind forwards these are: (1) the **postero-inferior lobule,** a large subdivision which bounds the great horizontal fissure on its under aspect; (2) the **biventral lobule** (lobulus biventer) which lies in front of the postero-inferior lobule, and is partially divided into two parts by a curved fissure which traverses its surface; (3) the **tonsil** or **amygdala** (tonsilla), a small rounded lobule which bounds the fore-part of the vallecula, and is lodged in a deep concavity on

the inner aspect of the biventral lobule; (4) the **flocculus**, a minute lobule situated on the middle peduncle of the cerebellum in front of, and partially overlapped by, the anterior border of the biventral lobule.

These lobules, with the corresponding portions of the vermis inferior, constitute the lobes on the under surface of the cerebellum. Still, it should be noted that, just as in the case of the upper surface of the organ, this subdivision is to some extent artificial, and is not in every particular provided with a sound morphological basis.

Lobus Tuberis.—The tuber valvulæ, which forms the most posterior part of the vermis inferior, is composed of several transversely arranged folia which, on either side, run directly into the postero-inferior lobule. The three parts of the lobus tuberis are thus linked together.

The postero-inferior lobule, which is wider towards the vallecula than it is further out, is traversed by two or it may be three curved fissures. The most anterior of these cuts off a narrow, curved strip of cerebellar surface, which presents a more or less uniform width throughout its whole length. This is the so-called **lobulus gracilis.**

Lobus Pyramidis.—The pyramid is connected with the biventral lobule on each side by an elevated ridge which crosses the sulcus valleculæ. The term lobus pyramidis is applied to the three lobules, which are thus associated with each other.

The pyramid is separated from the tuber valvulæ by a deep furrow which has been termed by Elliot Smith the **suprapyramidal fissure.** It is in a measure continuous with the curved fissure, which on the under surface of the hemisphere intervenes between the biventral lobule and the lobulus gracilis or fore part of the postero-inferior lobule. The name applied to the latter fissure by Elliot Smith is **fissura parapyramidalis.**

Lobus Uvulæ.—The uvula is a triangular elevation of the vermis inferior. It lies between the two tonsils, and is connected with each of these by a low-lying

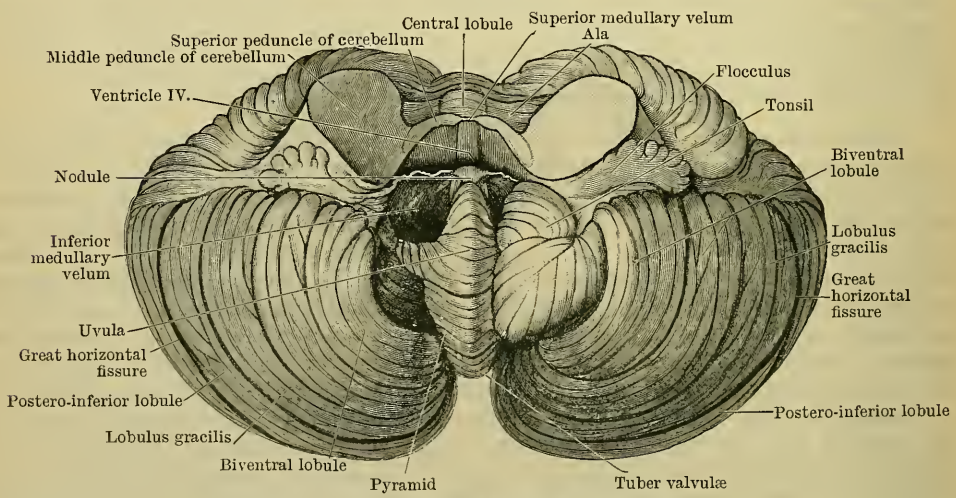


FIG. 409.—LOWER SURFACE OF THE CEREBELLUM.

The tonsil on the right side has been removed so as to display more fully the inferior medullary velum and the furrowed band.

band-like ridge of gray matter scored by a few shallow furrows, and in consequence termed the **furrowed band.** The two tonsils and the uvula form the lobus uvulæ.

Between the pyramid and the uvula there is a deep cleft which may be termed the **infra-pyramidal fissure** (the fissura secunda of Elliot Smith). This is more or less directly connected with the **retrotonsillar fissure** which curves round the tonsil. The large size of the tonsil is characteristic of the brain of man and the anthropoid apes.

Lobus Noduli.—The lobus noduli comprises the nodule and the flocculus of each side, with a delicate connecting lamina of white matter termed the **inferior medullary velum.**

The cleft between the nodule and the uvula is termed the **postnodular fissure** (Elliot Smith); that between the flocculus and the biventral lobule is called the **floccular fissure.**

The flocculus will usually be observed to be partially divided into two pieces. The smaller hinder portion, which, as a rule, is completely overlapped by the overhanging edge of the biventral lobule, is the **paraflocculus.** This assumes very large proportions in certain of the lower mammals.

Arrangement of the Gray and White Matter of the Cerebellum.—The white matter of the cerebellum forms a solid compact mass in the interior, and over this is spread a continuous and uniform layer of gray matter. In each lateral hemisphere the white central core is more bulky than in the median lobe or worm, in which the central white matter is reduced to a relatively thin bridge thrown across between the two lateral hemispheres. The white matter in the interior of the median lobe or worm is termed the **corpus trapezoides.** When sagittal sections are made through the cerebellum, the gray matter on the surface stands out clearly from the white matter in the interior. Further, from all parts of the surface of

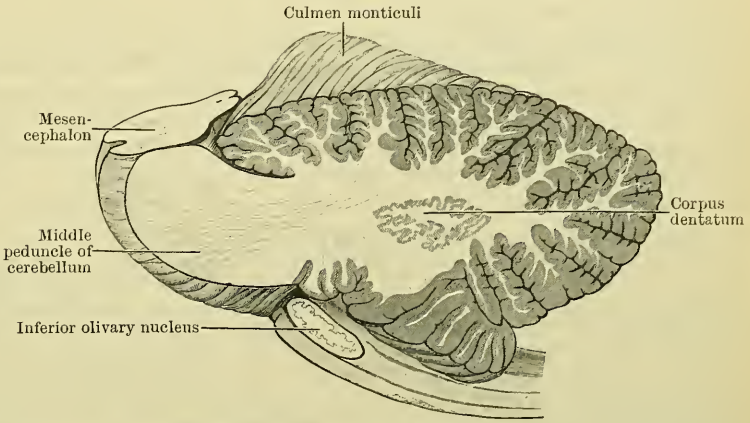


FIG. 410.—SAGITTAL SECTION THROUGH THE LEFT LATERAL HEMISPHERE OF THE CEREBELLUM,

Showing the "arbor vitæ" and the corpus dentatum.

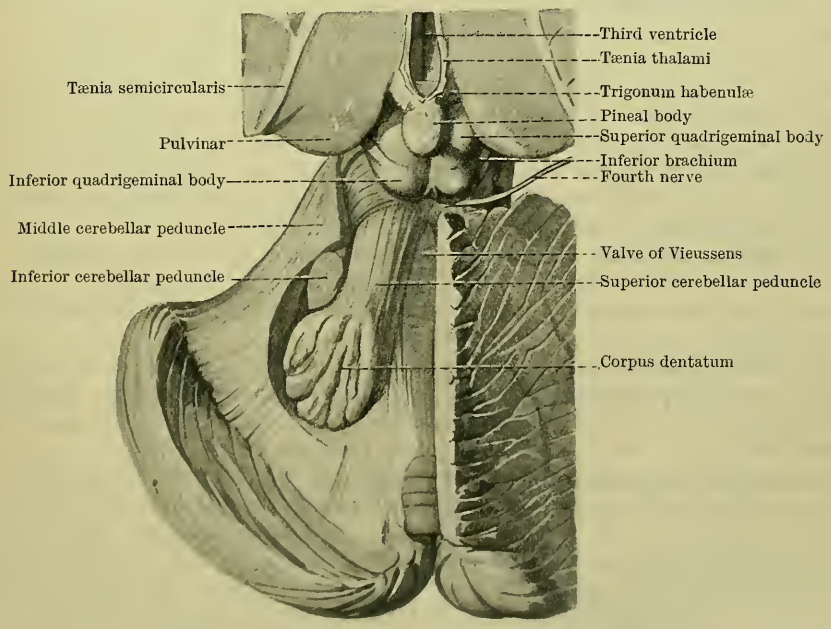


FIG. 411.—From a dissection by Dr. Edward B. Jamieson in the Anatomical Department of the University of Edinburgh. The corpus dentatum is displayed from above and the superior cerebellar peduncle has been traced from it to the mesencephalon.

the central core stout stems of white matter are seen projecting into the lobes of the cerebellum. From the sides of these white stems secondary branches proceed

at various angles, and from these again tertiary branches are given off. Over the various lamellæ of white matter thus formed the gray cortex is spread, and the fissures on the surface show a corresponding arrangement, dividing up the organ into lobes, lobules, and folia. When the cerebellum is divided at right angles to the general direction of its fissures and folia, a highly arborescent appearance is thus presented by the cut surface. To this the term **arbor vitæ cerebelli** is applied.

Corpus Dentatum and other Gray Nuclei in the White Matter of the Cerebellum.—Embedded in the midst of the mass of white matter which forms the central core of each lateral hemisphere there is an isolated nucleus of gray matter, which presents a strong resemblance to the inferior olivary nucleus of the medulla. It is called the **corpus dentatum** (nucleus dentatus), and it consists of a corrugated or plicated lamina of gray matter, which is folded on itself so as to enclose, in a flask-like manner, a portion of the central white matter (Figs. 410 and 411). This gray capsule is not completely closed. It presents an open mouth, termed the hilum, which is directed inwards and upwards, and out of this stream the great majority of the fibres of the superior cerebellar peduncle.

Three small additional masses of gray matter are also present on either side of the mesial plane in the central white matter of the cerebellum. These are termed the nucleus emboliformis, the nucleus globosus, and the nucleus fastigii. The **nucleus emboliformis** or **embolus** is a small lamina of gray matter which lies immediately internal to the hilum of the corpus dentatum, being thus related to it somewhat in the same manner that the mesial accessory olivary nucleus is related to the main inferior olivary nucleus. The **nucleus globosus** lies internal to the embolus and on a somewhat deeper horizontal plane. The **nucleus fastigii** or **roof nucleus** is placed in the white substance of the worm (corpus trapezoides) close to the mesial plane and its fellow of the opposite side. It is, therefore, situated on the mesial aspect of the nucleus globosus.

Although isolated from the gray matter of the surface, these small nuclei and the corpus dentatum are connected at certain points with each other. The corpus dentatum and the embolus present a structure very similar to that of the inferior olivary nucleus. In the nucleus globosus and the nucleus fastigii the cells are somewhat larger in size.

Cerebellar Peduncles.—These are three in number on each side, viz. the middle, the inferior, and the superior (Fig. 391, p. 487). The fibres of which they are composed all enter or emerge from the white medullary centre of the cerebellum.

The **middle peduncle** is much the largest of the three, and has already been described on pp. 486 and 501. It is formed by the transverse fibres of the pons, and it enters the cerebellar hemisphere on the outer aspect of the other two peduncles. The lips of the anterior part of the great horizontal fissure are separated widely from each other to give it admission (Fig. 409). Within the cerebellar hemisphere its fibres are distributed in two great bundles. Of these, one, composed of the upper transverse fibres of the pons, radiates out in the lower part of the hemisphere; whilst the other, consisting of the lower transverse fibres of the pons, spreads out in the upper part of the hemisphere.

The **inferior peduncle** is simply the restiform body of the medulla. After leaving the medulla it ascends for a short distance on the dorsal surface of the pons and then turns sharply backwards, to enter the cerebellum between the other two peduncles.

The **superior peduncle**, as it issues from the cerebellum, lies close to the inner side of the middle peduncle (Fig. 409). Its further course upwards on the dorsum of the pons to the inferior quadrigeminal body has been previously described (pp. 486 and 503).

Connexions established by the Peduncular Fibres.—The fibres of the **middle peduncle** are both afferent and efferent. The connexions which they establish in the pons are described on p. 501. The efferent fibres arise from cells in the gray cortex of the lateral hemisphere (also probably to some small extent in the cortex of the vermis), and end in connexion with the cells of the nucleus pontis, and likewise in the tegmental part of the pons. The afferent fibres, arising in the pons, end in the gray cortex of the lateral hemisphere of the cerebellum, and perhaps also in the cortex of the worm.

The **inferior peduncle** is also composed of afferent and efferent fibres (see p. 496); only the more important connexions which these establish in the cerebellum can be touched on here. The principal afferent strand is the *direct cerebellar tract*. The fibres of this strand end in the cortex of the superior worm on both sides of the mesial plane, but chiefly on the opposite side. The *cerebello-olivary fibres* are also probably afferent. It

appears that they end in connexion with cells in the cortex of both the worm and hemisphere, and also cells in the nucleus dentatus. The numerous *arcuate fibres* which enter the inferior peduncle establish connexions with cells in the cortex of the lateral hemisphere and of the worm.

The **superior peduncle** is an efferent tract. The majority of its fibres come from the cells of the nucleus dentatus, whilst a small proportion appear to come from the cerebellar cortex. According to Risien Russell, the fibres which form the dorsal edge of the band come from the opposite side of the cerebellum and cross the mesial plane to join the peduncle.

Our knowledge of the connexions of the peduncles of the cerebellum has been greatly extended by Ferrier and Aldren Turner; and the account which is given above, and also at p. 501, is largely derived from their memoir on this subject.

Commissural and Association Fibres.—In addition to those fibres of the white medullary centre which belong to the system of peduncles, there are others which have exclusively cerebellar connexions. Thus the various folia are bound together by numerous **association fibres**, which pass from one folium into another around the bottom of the intervening fissure. Tracts of transversely-directed **commissural fibres** cross the mesial plane in the white centre of the vermis, connecting corresponding parts of opposite sides. These, in some measure, are analogous to the corpus callosum of the cerebrum. The **roof nuclei** are also closely bound by connecting fibres with the cortex.

Medullary Vela.—The medullary vela are closely associated with the cerebellar peduncles. They consist of two thin laminæ of white matter, which are projected out from the white central core of the cerebellum.

The **superior medullary velum** is described on p. 486. Laterally, it is continuous with the dorsal edges of the superior cerebellar peduncles; whilst, inferiorly, it is prolonged downwards and backwards under the lingula and the central lobule of the superior worm, to become continuous with the central white matter or corpus trapezoides of the worm.

The **inferior medullary velum** is more complicated in its connexions. It presents much the same relations to the nodule of the inferior vermiform process that the superior velum presents to the lingula of the superior vermiform process. It is a wide thin lamina of white matter—so thin that it is translucent—which is prolonged out from the white centre of the cerebellum above the nodule. From the nodule it stretches outwards to the flocculus on each side, thereby bringing these three small portions of the cerebellum into association with each other (Fig. 409). Where it issues from the white matter of the cerebellum it is in contact with the superior medullary velum, but, as the two laminæ are traced forwards, they diverge from each other. The superior velum is carried upwards between the two superior cerebellar peduncles, whilst the inferior medullary velum is curved forwards and then downwards round the nodule, and ends at a variable point in a free, slightly thickened, crescentic edge. The cavity of the fourth ventricle is carried backwards into the cerebellum between the two vela, which thus form a peaked and tent-like root for it.

Relation of the Tract of Gowers to the Superior Medullary Velum.—The ascending tract of Gowers has been noticed in connexion with the lateral column of the cord (p. 469). The fibres which compose it are carried upwards through the formatio reticularis grisea of the medulla and the corresponding part of the tegmental portion of the pons. In this part of its course the fibres are scattered and do not form a compact strand. Reaching the upper end of the pons the tract turns backwards, enters the superior medullary velum, and proceeds downwards in it into the cerebellum.

Roof of the Fourth Ventricle.—In its upper part the roof of the fourth ventricle is formed by the superior medullary velum as it stretches across between the two superior cerebellar peduncles, and also, to some extent, by the approximation of these peduncles themselves as they approach the mesencephalon.

In its lower part the roof of the ventricle is exceedingly thin and is not all formed of nervous matter. The inferior medullary velum enters into its formation, and, where this fails, the epithelial lining of the cavity, supported by pia mater, is carried downwards towards the lower boundaries of the floor of the ventricle. At the lowest part of the calamus scriptorius, and also along each lateral boundary of

the floor, a thin lamina of white matter is carried for a short distance over the epithelial roof. The small semilunar lamina which stretches across between the lower parts of the two clavæ at the calamus scriptorius and overhangs the opening

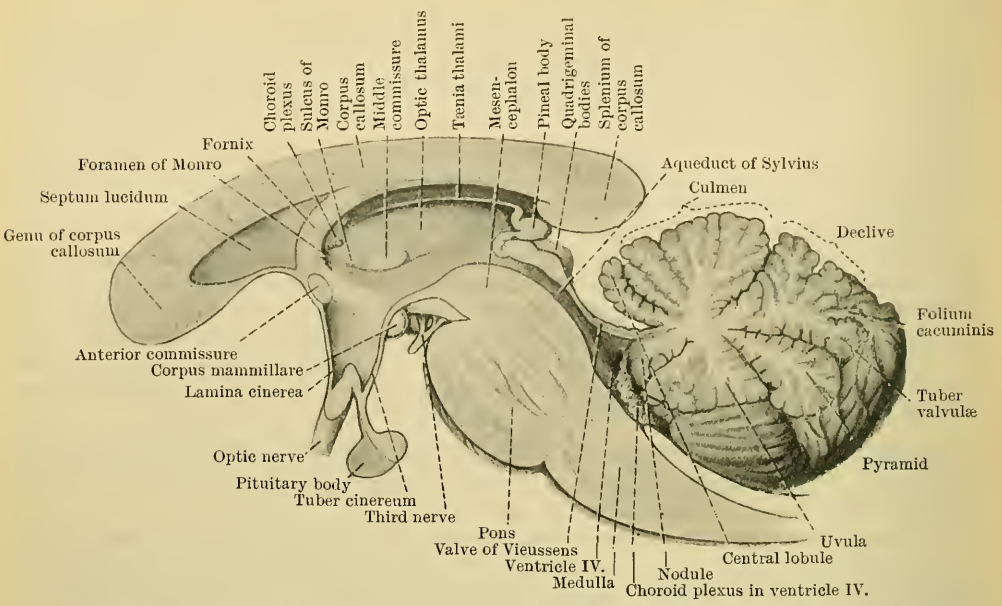


FIG. 412.—MESIAL SECTION THROUGH THE CORPUS CALLOSUM, THE MESENCEPHALON, THE PONS, MEDULLA, AND CEREBELLUM.

Showing the third and fourth ventricles joined by the aqueduct of Sylvius.

of the central canal is termed the **obex** (Fig. 391, p. 487). The lamina in connexion with the lateral boundary of the ventricular floor is more extensive, and is called the **ligula** (Figs. 388 and 390). It begins on the clava and passes upwards over the cuneate tubercle to the restiform body. On the outer surface of the restiform body it turns outwards so as to bound the lateral recess of the ventricle below, and in some cases it may be seen to become continuous around the extremity of the lateral recess with the inferior medullary velum.

A short distance above the calamus scriptorius there is, in the mesial plane, an opening in the epithelial and pial roof of the ventricle, by which the cavity of the ventricle communicates with the subarachnoid space. This opening is termed the **foramen of Majendie.** There is also an aperture of a similar nature in the epithelial and pial roof at the extremity of each lateral recess.

Two **choroid plexuses**, or highly vascular infoldings of the pia mater, invaginate the lower part of the roof of the fourth ventricle. These are placed one on either side of the mesial plane, and, although they appear to lie within the cavity, they are in reality excluded from it by the epithelial lining of the ventricle, which covers over and is adapted to every sinuosity on their surface.

Two lateral offshoots from these longitudinal choroid plexuses proceed outwards, and protrude in a similar manner into the lateral recesses.

MINUTE STRUCTURE OF A CEREBELLAR FOLIUM.

A cerebellar folium is composed of a central core of white matter, covered by a layer of gray matter. The gray cortex is arranged in two very evident layers, viz. a superficial **molecular layer** and a subjacent rust-coloured **granular layer.** Between these strata a single layer of large cells, termed the **cells of Purkinje,** are disposed in the form of a very nearly continuous sheet. The cells of Purkinje constitute the most characteristic, and probably the most essential, constituents of the cerebellar cortex.

The **cells of Purkinje** are most numerous on the summit of the folium. At the bottom of the sulci which intervene between the folia they become fewer in number, and, therefore, looser in their arrangement. Each consists of a large flask-shaped or pyriform

cell body, the narrow end of which projects into the molecular layer, whilst the thicker, deeper end rests on the granular layer. From the latter arises a **single axon**, which passes into the granular layer and presents the peculiarity of almost immediately assuming its medullary sheath. From this axon a few collateral branches soon arise, which, taking a recurrent course, enter the molecular layer, to end in connexion with certain of the adjoining cells of Purkinje. They would seem to have the function of binding together adjacent cells, and thus enabling them to carry on their operations in harmony with each other.

The **dendritic processes** spring from the narrow end of the cell either in the form of one or perhaps two stout stalks. These ascend into the molecular layer, branching and rebranching until an aborescent arrangement of extraordinary richness and extent results. The dendritic branches extend throughout the entire thickness of the molecular layer, and the branching takes place in one plane only, viz. in a plane which is transverse to the long axis of the folium. Consequently, it is only when transverse sections are made through a folium that the full dendritic effect is obtained; in sections made parallel to the long axis of the folium the cells are seen in profile, and are observed to occupy quite a narrow area (Fig. 414). The branching of the dendrites of a cell of Purkinje may, therefore, be compared to that which takes place in the case of a fruit-tree which is trained against a wall.

FIG. 413.—TRANSVERSE SECTION THROUGH A CEREBELLAR FOLIUM (after Kölliker).

Treated by the Golgi method.

P. Axon of cell of Purkinje.
F. Moss fibres.
K and K^1. Fibres from white core of folium ending in molecular layer in connexion with the dendrites of the cells of Purkinje.
M. Small cell of the molecular layer.
GR. Granule cell.
GR^1. Axons of granule cells in molecular layer cut transversely.
M^1. Basket-cells.
ZK. Basket-work around the cells of Purkinje.
GL. Neuroglial cell.
N. Axon of an association cell.

In the **molecular layer** the cells are not particularly numerous, and of these the most characteristic are the **basket-cells** which lie in the deeper part of the layer. In addition to numerous dendrites the basket-cell gives off an axon which runs transversely, as regards the long axis of the folium, between the planes of adjacent dendritic arborisations of the cells of Purkinje. At first very fine these axons gradually become coarse and thick, and at intervals they give off collaterals which run towards the bodies of the cells of Purkinje. Reaching these, they break up into an enormous number of fine terminal branches, which enclose the cells of Purkinje, as well as the short non-medullated portions of their axons, in a close basket-work of fine filaments.

The **granular layer** is, for the most part, composed of large numbers of small granule-like bodies closely packed together. Each of these possesses a somewhat large nucleus, with a very small amount of surrounding protoplasm. From the cell body three or four, or perhaps five, dendrites and one axon proceed. The **dendrites** are short and radiate out from different aspects of the cell body. They end in tufts of claw-like twigs, which either embrace or are otherwise in contact with neighbouring granule cells. The whole multitude of granule cells, therefore, are brought into intimate connexion with each other. The **axon** passes into the molecular layer, in which it ends at a varying

distance from the surface by dividing into two branches. These diverge so sharply from each other that they almost form a right angle with the parent stem, and they run parallel to the long axis of the folium, threading their way between the branches of the various dendritic planes of the cells of Purkinje and entering into contact association with them. When the great number of granule cells is borne in mind, and the fact that each sends an axon into the molecular layer, the important part which these fibres, with their longitudinal branches, take in building up the molecular layer will be understood. They are found pervading its entire thickness—from the surface down to the bodies of the cells of Purkinje.

Near the cells of Purkinje a few scattered cells are seen in the granular layer of a different kind. These are much larger than the ordinary granule cells, and are probably of the nature of association cells. They are stellate in form, and have numerous long branching dendrites and an axon which divides up in the granular layer to a singular extent.

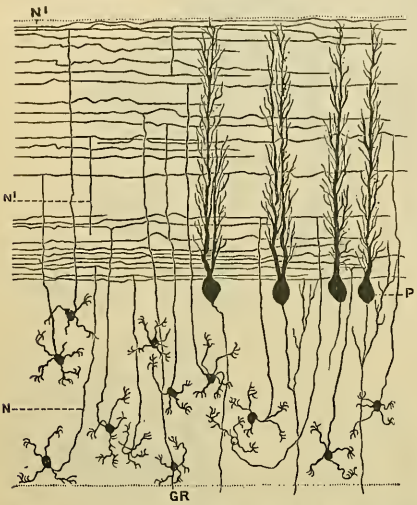


Fig. 414.—Section through the Molecular and Granular Layers in the Long Axis of a Cerebellar Folium (after Kölliker).

Treated by the Golgi method.

P. Cell of Purkinje.
GR. Granule cells.
N. Axon of a granule cell.
N¹. Axons of granule cells in molecular layer.

The **white centre** of the folium becomes thinner as it approaches the summit. This is due to the fibres which compose it gradually entering the gray matter on the surface. These fibres are of three kinds, viz.: (1) axons of the cells of Purkinje; (2) fibres which apparently end in the granular layer; and (3) fibres which end in the molecular layer.

The **axons of the cells of Purkinje** are medullated fibres which, entering the white centre of the folium, form a not inconsiderable part of it.

The fibres which end in the granular layer are called **moss-fibres.** This name is applied to them because, in the granular layer, they present at certain points moss-like thickenings, from which short rough twigs proceed.

The fibres which proceed into the molecular layer give off few or perhaps no branches as they traverse the granular layer. In the deeper part of the molecular layer they break up into varicose branches, which twine around the primary and secondary stems of the Purkinje dendrites.

Entering into the constitution of the **molecular layer** are the following elements: (1) dendrites of the cells of Purkinje; (2) basket-cells and somewhat smaller cells nearer the surface; (3) axons of the granule cells, with their longitudinally arranged branches; (4) the terminations of certain fibres from the white core of the folium, which end in contact with the Purkinje dendrites.

In the **granular layer** are found: (1) granule cells; (2) larger stellate association cells; (3) axons of the cells of Purkinje; (4) moss-fibres; (5) fibres traversing this layer, to end in the molecular layer.

THE DEEP CONNEXIONS OF THE CRANIAL NERVES ATTACHED TO THE MEDULLA AND PONS.

There are twelve pairs of cranial nerves, of which the lower eight are attached to the medulla and pons Varolii. From above downwards these are named the fifth or trigeminal, the sixth or abducent, the seventh or facial, the eighth or auditory, the ninth or glossopharyngeal, the tenth or vagus, the eleventh or spinal accessory, and the twelfth or hypoglossal. The hypoglossal, the spinal accessory, the greater part of the facial, the abducent, and the motor root of the trigeminal are efferent nerves; the auditory, the pars intermedia of the facial, and the sensory root of the trigeminal are purely afferent nerves; whilst the vagus and the glossopharyngeal are composed of both efferent and afferent fibres. In all cases afferent fibres arise from ganglionic cells placed outside the brain and penetrate the brain-stem, to end in connexion with the cells of certain **nuclei of termination.** Efferent

fibres, on the other hand, take origin within the brain as the axons of cells which are grouped together in certain places in the form of **nuclei of origin.**

Nuclei of Origin, or Motor Nuclei.—In the spinal cord the nuclei of origin are represented by elongated columns of cells which run more or less continuously in the anterior horn of gray matter of successive cord-segments, and from these the series of efferent anterior nerve-roots take origin. In the medulla and pons the nuclei of origin, or, in other words, the motor nuclei of the individual nerves become, for the most part, discontinuous, and are represented by certain isolated clumps of compact gray matter, in which are placed the clusters of cells from which the fibres of the efferent nerves arise. The nucleus ambiguus, however, which consists of a column of cells from which root fibres of the medullary part of the spinal accessory, of the vagus, and possibly also of the glossopharyngeal are derived, is an exception to this rule. At the decussation of the pyramids, the anterior horn of gray matter of the cord is broken up by the intercrossing bundles into a detached head and a basal part which remains in relation with the ventro-lateral aspect of the central canal. Certain of the efferent or motor nuclei of the medulla and pons lie in the line of the basal portion of the ventral horn of gray matter of the spinal cord, and thus close to the mesial plane. These are termed **mesial nuclei of origin,** and are met with at different levels in the brain-stem. This group comprises the hypoglossal nucleus, the dorsal motor nucleus of the vago-glossopharyngeal nerve, the abducent nucleus (and, in the mesencephalon, the trochlear nucleus and the oculo-motor nucleus). Other motor nuclei of origin are present in the form of isolated clumps or columns of gray matter, which lie at different levels in the medulla and pons in the line of the detached head of the anterior horn of gray matter. They are the nucleus ambiguus of the spinal accessory, the vagus and glossopharyngeal, the facial nucleus, and the nucleus of the motor root of the trigeminal nerve. From their position in the tegmental substance of the medulla and pons they constitute a group to which the name of **lateral motor nuclei** is applied.

The different nuclei of origin of the efferent fibres which belong to the various cranial nerves, both mesial and lateral, are connected with the motor area of the cerebral cortex by fibres from the pyramidal tract, which enter the nuclei and end in connexion with their cells.

Nuclei of Termination.—In the brain the nuclei of termination are likewise discontinuous, and are represented by more or less isolated clusters or columns of cells. Unlike the motor nuclei, however, these nuclei show no regular or definite position within the medulla and pons. Some are found in the gray matter which surrounds the central canal, and in its continuation upwards as the gray matter in the floor of the fourth ventricle; others are placed in the tegmental substance; whilst two actually lie on the surface of the brain-stem, viz. the lateral and ventral nuclei of the cochlear or outer division of the auditory nerve.

The axons of the cells of the nuclei of termination enter the reticular formation of the tegmental substance as arcuate fibres, and, crossing the mesial plane, are carried upwards in the tegmental substance of the opposite side to establish direct connexions with the optic thalamus and indirect connexions with the cerebral cortex.

Hypoglossal Nerve (nervus hypoglossus).—The nucleus of origin of the hypoglossal nerve, the motor nerve of the tongue, lies in the substance of the medulla oblongata. It is composed of several groups of large multipolar cells, which closely resemble the cells in the ventral horn of gray matter in the spinal cord, and is pervaded by an intricate network of fine fibrils. In form it is elongated and rod-like, and in length it is somewhere about 18 mm. It extends from a point immediately above the decussation of the pyramids up to the level of the striæ acusticæ. The lower portion of the nucleus is thus placed in the closed part of the medulla (Fig. 397, p. 493), whilst its upper part is situated in the open part of the medulla (Fig 402, p. 497). The former lies in that part of the central gray matter which is continuous with the basal part of the ventral horn of gray matter of the cord. It is thus placed on the ventral and lateral aspect of the central canal, close to the mesial plane and the corresponding nucleus of the opposite side. The upper part of the nucleus occupies a position in the gray matter on the floor of

the fourth ventricle, subjacent to the inner part of the surface area, which has been described under the name of the trigonum hypoglossi. Within the nucleus the axons of the cells arrange themselves in converging bundles of fine fibres, which come together and leave the ventral aspect of the nucleus as the fasciculi of the nerve. The nerve bundles thus formed traverse the entire antero-posterior thickness of the medulla between the formatio reticularis grisea and the formatio reticularis alba, and emerge on the surface in linear order at the bottom of the furrow between the olivary eminence and the pyramid. In the substance of the medulla the root-bundles of the hypoglossal pass between the main inferior olivary nucleus and the mesial accessory olivary nucleus, and many of them on their way to the surface pierce the ventral lamina of the main olivary nucleus.

No decussation between the nerves of opposite sides takes place in the medulla, but commissural fibres pass between the two nuclei (Kölliker). Further, numerous fibres from the opposite pyramidal tract enter the nucleus and end in connexion with its cells. The nucleus is thus brought into connexion with the motor area of the opposite side of the cerebral cortex.

Spinal Accessory Nerve (nervus accessorius).—The spinal accessory is likewise a motor nerve, and it is generally described as consisting of a spinal and a medullary or accessory part.

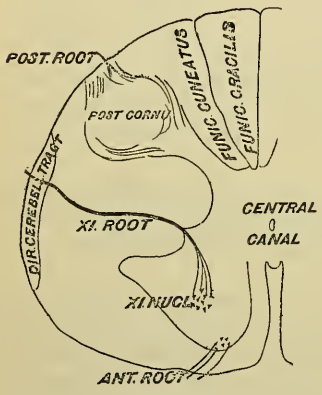


Fig. 415.—Diagram of the Spinal Origin of the Spinal Accessory Nerve (after Bruce).

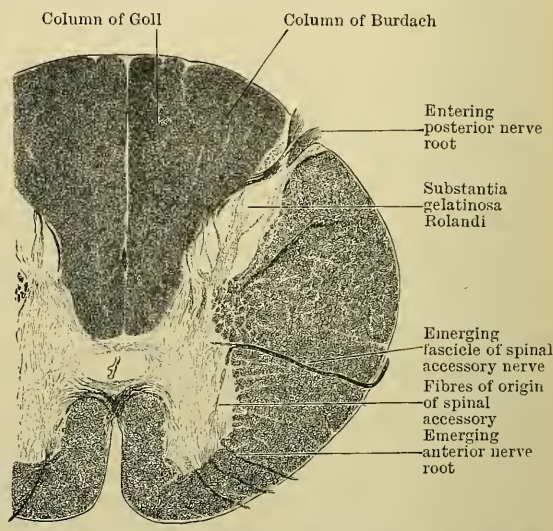


Fig. 416.—Section through the Upper Part of the Cervical Region of the Cord (Orang), Showing the origin of the spinal part of the spinal accessory nerve.

The **spinal part** of the nerve emerges by a series of roots which issue from the surface of the lateral column of the upper part of the cord as low down as the fifth cervical nerve. These take origin in a column of cells situated in the anterior horn of gray matter of the cord close to its lateral margin, and immediately behind the nerve-cells which give rise to the fibres of the anterior roots of the upper five cervical nerves. The cells of the accessory nucleus are large, multipolar, and in every respect similar to the motor cells of the spinal nerves. The axons from these cells leave the dorsal aspect of the nucleus in converging groups to form the root-bundles of the nerve. These, in the first place, proceed straight backwards in the anterior horn of gray matter. Reaching the bay between the two horns of gray matter, they turn sharply outwards into the white matter and traverse the lateral column to gain their points of exit from the cord. At the decussation of the pyramids, root-bundles, which join the spinal accessory nerve, are seen to proceed from the detached head of the anterior horn of gray matter.

The **medullary part** of the spinal accessory nerve has its nucleus of origin in the medulla; and its root-bundles, as they proceed outwards from this, can be distin-

guished by the fact that they pursue a course on the ventral side of the spinal root of the trigeminal nerve, whereas the vagus roots, with which they are apt to be confused, pass through or lie on the dorsal aspect of the trigeminal root (Kölliker). The nucleus of origin of the medullary part of the accessory nerve is formed by the same column of cells which constitutes the **nucleus ambiguus**, and which, at a higher level, gives motor fibres to the vagus and glossopharyngeal nerves.

The part of the spinal accessory nerve which takes origin in the spinal cord supplies the sterno-mastoid and trapezius muscles. The medullary or accessory portion joins the vagus, and through the external and recurrent laryngeal nerves it supplies the muscles of the larynx. The portion of the nucleus ambiguus from which it arises has thus been termed the laryngeal nucleus (Edinger).

Collaterals and fibres of the opposite pyramidal tract end in connexion with the cells of origin of the accessory nerve, and thus bring its nucleus into connexion with the motor area of the cerebral cortex. Fibres also from the posterior roots of the spinal nerves (afferent or sensory fibres) end in the nucleus.

Vagus and Glossopharyngeal Nerves (nervus vagus, nervus glossopharyngeus).—These nerves present similar connexions with the brain, and they may therefore be studied together. The greater part of both nerves is composed of afferent fibres, which arise outside the brain-stem from ganglionic cells placed in relation to the nerve-trunks. Both nerves likewise possess motor or efferent fibres, which spring from two special nuclei of origin situated within the medulla and termed respectively the **dorsal motor nucleus** and the **nucleus ambiguus**. The afferent ganglionic fibres of the vagus and glossopharyngeal enter the brain by a series of roots which penetrate the medulla along the outer or ventral side of the restiform body. Within the medulla they separate into two sets, viz. a series of bundles (chiefly composed of vagus fibres), which end in the **dorsal nucleus of termination** of the vagus and glossopharyngeal nerves, and another series of bundles (chiefly composed of glossopharyngeal fibres), which join a conspicuous longitudinal tract of fibres called the **fasciculus solitarius**.

The **dorsal nucleus** (Figs. 398, p. 495, and 402, p. 497) of the vagus and glossopharyngeal nerves is mixed, and contains both motor cells which give origin to efferent fibres and cells around which afferent fibres of the vagus, and possibly also of the glossopharyngeal nerve, break up into terminal arborisations. It very nearly equals in length the nucleus of the hypoglossal nerve, with which it is closely related. Above, it reaches as high as the striæ acusticæ, whilst below its lower end falls slightly short of that of the hypoglossal nucleus. In specimens stained by the Weigert-Pal method the two nuclei offer a marked contrast. The hypoglossal nucleus presents a dark hue, owing to the enormous numbers of fine fibres which twine in and out amidst its cells; the vago-glossopharyngeal dorsal nucleus is pale from the scarcity of such fibres within it. In the closed part of the medulla the dorsal vago-glossopharyngeal nucleus lies in the central gray matter immediately behind the hypoglossal nucleus, and upon the lateral aspect of the central canal; in the open part of the medulla it lies in the gray matter of the floor of the fourth ventricle, immediately to the outer side of the hypoglossal nucleus and subjacent to the surface area termed the trigonum vagi.

The cells in the portion of the dorsal nucleus which acts as a *nucleus of termination* are spindle-shaped in form and similar to those found in the posterior horn of gray matter in the cord. In connexion with these cells, the greater number of the afferent fibres of the vagus nerve, and a small proportion of the afferent fibres of the glossopharyngeal nerve end in fine terminal arborisations. A small part of the upper portion of the nucleus may be said to belong to the glosso-pharyngeal nerve and the remainder of the nucleus to the vagus nerve.

The cells which constitute the *dorsal motor* or *efferent nucleus* as seen in transverse section appear in a more or less compact cluster, which lies immediately to the outer side of the hypoglossal nucleus. These cells, although very conspicuous, are not so large as those in the hypoglossal nucleus, nor as those in the anterior horn of gray matter of the cord; nor do they stain so deeply.

The **fasciculus solitarius** (Figs. 397, p. 493; 398, p. 495; and 402, p. 497) is a round bundle of longitudinal fibres which forms a very conspicuous object in transverse sections through the medulla. It begins at the upper limit of the medulla,

and can be traced downwards through its whole length. Its precise point of termination is not known, but it is believed that it is carried for some distance downwards into the upper part of the cord, viz. to the level of the fourth cervical nerve, according to Kölliker. The relations of the fasciculus solitarius are not the same in all parts of its course. It lies immediately to the outer side of the dorsal vago-glossopharyngeal nucleus; but whereas in the upper part of the medulla it is situated somewhat on the ventral side of that nucleus, in the lower closed part of the medulla it is placed on its dorsal aspect. Throughout its entire length it is intimately associated with a column of gelatinous gray substance which constitutes the nucleus of termination in which its fibres end. When traced from above downwards, the solitary tract is observed to become gradually smaller from the loss of fibres which it thus sustains. The great bulk of the solitary tract is formed of fibres derived from the glossopharyngeal nerve; only a few of the afferent fibres of the vagus enter it. As the fibres of the two nerves join the tract they immediately turn downwards, and at different levels come to an end in the associated gelatinous gray nucleus.

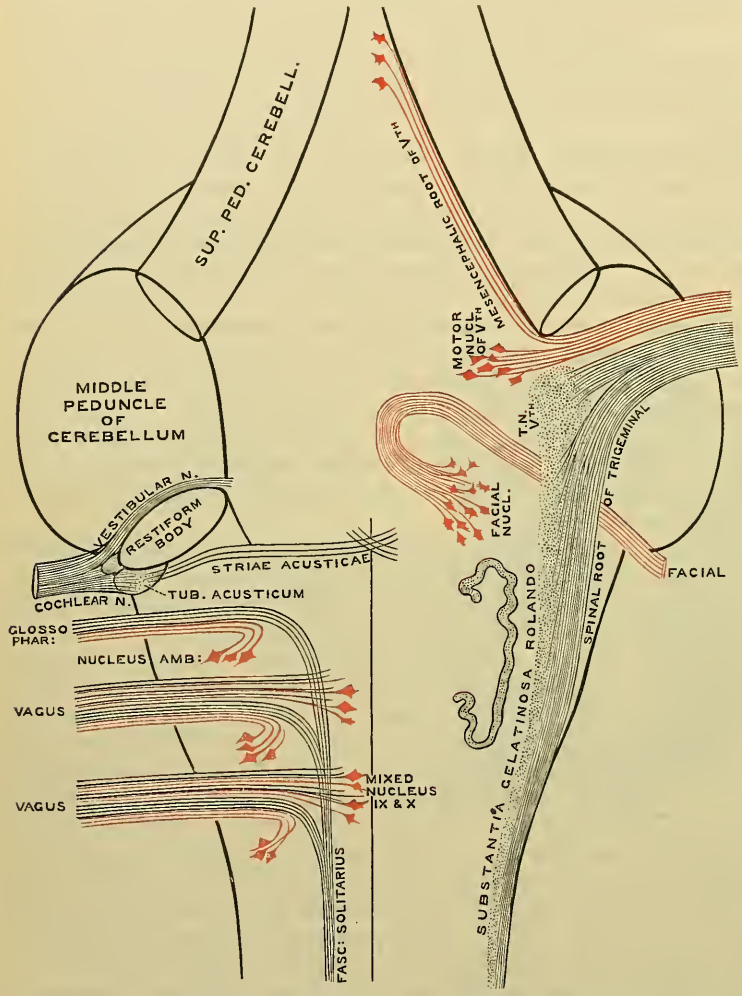


FIG. 417.—DIAGRAM, showing the brain connexions of the vagus, glossopharyngeal, auditory, facial, abducent, and trigeminal nerves.

As the root-bundles of the vagus and the glossopharyngeal nerves traverse the substance of the medulla in a backward and inward direction to reach the fasciculus solitarius and the dorsal nucleus of termination, they pass through the spinal root of the trigeminal nerve and the substantia gelatinosa Rolandi associated with it. The term **ascending root** is sometimes applied to the fasciculus solitarius; but as this conveys an altogether false conception of its character it should be discarded. The axons of the nucleus of termination and of the nucleus of the fasciculus solitarius form central connexions with other parts of the brain, but these have not as yet been completely elucidated.

The **dorsal efferent nucleus** gives off fibres which join the afferent fibres of the vago-glossopharyngeal rootlets as they traverse the medulla, and mixing with them they pass along the same path to emerge from the medulla.

The **nucleus ambiguus** (Figs. 398, p. 495, and 402, p. 497) also gives origin to

motor or efferent fibres which join the vagus and glossopharyngeal nerves. The cells which compose it are large, multipolar, and similar in every respect to the large cells in the ventral horn of gray matter of the spinal cord. These cells are arranged in a slender column which is best developed in the upper open part of the medulla. Here the nucleus can easily be detected in transverse sections as a small area of compact gray matter which lies in the formatio reticularis grisea, midway between the dorsal accessory olive and the substantia gelatinosa Rolandi. It therefore lies more deeply in the substance of the medulla than the mixed dorsal vago-glossopharyngeal nucleus. Kölliker states that it can be traced downwards as low as the level of the decussation of the fillet, and upwards as high as the place of entrance of the cochlear root of the auditory nerve. From its dorsal aspect the axons of the cells proceed, and in the first instance they pass backwards towards the floor of the fourth ventricle; then, bending suddenly outwards and forwards, they join the afferent roots of the vagus and possibly also of the glossopharyngeal nerves, and emerge from the brain in company with these.

Upon anatomical grounds it might be questioned whether the glossopharyngeal nerve contains any efferent fibres. It gives off, it is true, one motor branch, viz. to the stylo-pharyngeus muscle, but there are paths by means of which these fibres might enter the nerve other than by coming directly from the motor nuclei, which have been described in connexion with the vago-glossopharyngeal nerve-roots.

There is, further, some ground for the belief that all the fibres of the glossopharyngeal pass into the fasciculus solitarius. In a very instructive case described by Alexander Bruce in which the glossopharyngeal was destroyed in the jugular foramen by the pressure of a tumour, no degenerated fibres could be traced beyond the fasciculus solitarius.

Auditory Nerve (nervus acusticus).—This is a large nerve which joins the brain at the lower border of the pons Varolii and on the ventral aspect of the restiform body. It is an afferent nerve, and its fibres spring from bipolar ganglionic cells either within or in the immediate neighbourhood of the labyrinth or internal ear (see section dealing with the organs of sense). Reaching the brain the auditory nerve divides into two parts, viz. the nervus cochlearis and the nervus vestibularis, which present totally different connexions and apparently exercise absolutely distinct functions. In their further course these two divisions deviate from each other so as to embrace the restiform body—the vestibular part entering the pons on the inner or mesial aspect of the restiform body, whilst the cochlear part sweeps round its outer surface. Special nuclei of termination require to be studied in connexion with each part of the nerve.

The **cochlear nerve** is composed of finer fibres than the vestibular nerve, and these acquire their medullary sheaths at a later period. It is the true nerve of hearing, and its fibres end in a ganglion which lies in intimate relation to the restiform body, and which may be described as consisting of two parts. Of these one, called the **tuberculum acusticum** or the **lateral cochlear nucleus**, is a pyriform mass which is placed on the outer aspect of the restiform body—between it and the flocculus of the cerebellum. The second part, termed the **ventral cochlear nucleus**, does not extend so low down as the tuberculum acusticum. It is a wedge-shaped nuclear mass which is placed on the ventral aspect of the restiform body in the interval between the cochlear and vestibular divisions of the auditory nerve, after they have separated from each other. The fibres of the cochlear nerve enter these two ganglia and end around the cells in terminal arborisations, which are finer, closer, and more intricate than those met with in any other nerve nucleus in the brain.

The **vestibular nerve** enters the brain at a slightly higher level than the cochlear nerve and on the mesial aspect of the ventral cochlear nucleus. It forces its way backwards through the pons between the restiform body, which lies on its outer side, and the spinal root of the fifth nerve, which is placed on its inner side. Its fibres come to an end in three nuclei of termination, which are situated in the dorsal part of the pons and medulla, viz. (1) the principal nucleus or dorsal nucleus; (2) the nucleus of the descending root; and (3) the nucleus of Deiters.

The **principal nucleus** (Figs. 403, p. 500, and 418, p. 520) is a large diffuse nuclear mass, which lies in the floor of the fourth ventricle subjacent to the surface

district known as the *area acustica* (Fig. 391, p. 487). It is situated, therefore, in both the pons and the medulla to the outer side of the fovea superior and the fovea inferior. In transverse section it is prismatic in outline, and crossing the surface of its upper or pontine part immediately under the ependyma of the ventricle are the striæ acusticæ.

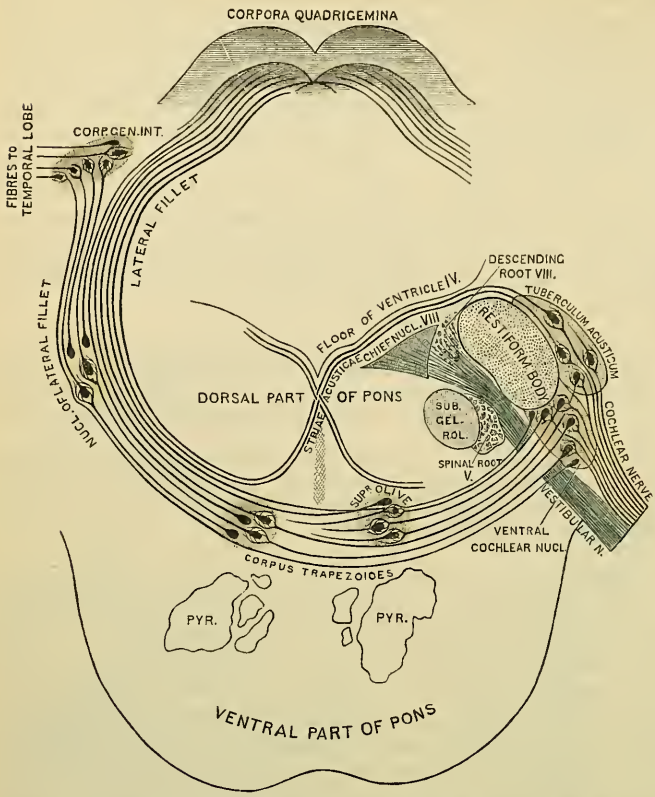


Fig. 418.—Central Connexions of the Cochlear and Vestibular Divisions of the Auditory Nerve.

(Diagram founded on drawings by Edinger and Ferrier and Turner.)

When the nervus vestibularis, as it traverses the brain, reaches the inner aspect of the dorsal portion of the restiform body, a very large proportion of its fibres turn vertically downwards in separate bundles and form the descending root of the vestibular nerve (Figs. 398, p. 495; 402, p. 497; 403, p. 500; 418, p. 520). This proceeds through the lower part of the pons into the medulla, in which it may be traced as far as the level of the decussation of the fillet. Associated with the descending root there is a column of gray matter, with nerve-cells strewn sparsely throughout it. This is the **nucleus of the descending root**, and the fibres end in fine arborisations around these nerve-cells.

The fibres of the vestibular nerve likewise end in the **nucleus of Deiters.** This nucleus is composed of a number of large and conspicuous multipolar nerve-cells, which are scattered amidst the bundles of the upper part of the descending root of the vestibular nerve. As it is traced upwards into the pons the nucleus gradually inclines backwards, and finally it occupies a place in the lateral wall of the fourth ventricle. It attains its greatest development at the level of the emerging part of the facial nerve, and this upper part is sometimes termed the **nucleus of Bechterew.**

Central Connexions of the Cochlear Nerve.—The cochlear nerve is brought into connexion with the inferior quadrigeminal body, and the corpus geniculatum internum of the opposite side by the fibres of the corpus trapezoides and the lateral fillet. But this connexion is not direct; the chain is composed of several separate links or neurons superimposed one over the other.

The fibres of the cochlear nerve end in the ventral cochlear nucleus and in the tuberculum acusticum. From the cells of these nuclei two tracts arise, viz. a **ventral tract**, composed of the fibres of the corpus trapezoides, and a **dorsal tract**, which is represented by the striæ acusticæ.

The **corpus trapezoides** (Figs. 418 and 419) is formed of the axons of the cells of the ventral cochlear nucleus, as well as certain of the axons of the cells of tuberculum acusticum. In the midst of the corpus trapezoides are lodged large cells which are known as the *nucleus trapezoideus*, and these give off axons which join the strand with which they are associated. Further, the *superior olive* forms an important internode in the path of the corpus trapezoides. Many of the fibres of the corpus trapezoides end in this

internode, whilst others are added to the tract from the cells of that nuclear mass. So constituted, the trapezial fibres cross the mesial plane and decussate with the corresponding fibres of the opposite side. Reaching the opposite superior olivary nucleus a further interchange of fibres takes place, and almost immediately after this the strand turns upwards and becomes the **lateral fillet** (Figs. 405, p. 503; 406, p. 504). But still another nucleus is interposed in its path, viz. the *nucleus of the lateral fillet*. Here some fibres are dropped, whilst from the nuclear cells others are acquired, and the lateral fillet then proceeds onwards without further interruption until it reaches the inferior quadrigeminal body and the corpus geniculatum internum, in which its fibres end. It is probable, however, that some likewise extend into the superior quadrigeminal body.

But the lateral fillet also includes the fibres of the **striæ acusticæ** of the opposite side. These fibres arise from the cells of the tuberculum acusticum, and arrange themselves in the conspicuous bundles which sweep round the dorsal aspect of the restiform body and proceed inwards across the floor of the fourth ventricle, immediately beneath the ependyma (Fig. 391, p. 487). Reaching the middle line they dip forwards into the substance of the medulla, and, crossing the mesial plane, they join the lateral fillet.

It is well to remember that the connexion between the terminal cochlear nuclei and the inferior quadrigeminal body is not altogether with that of the opposite side, as the foregoing description and the diagram (Fig. 418) might lead one to infer. A few fibres pass directly to the inferior quadrigeminal body of the same side, but none to the corresponding corpus geniculatum internum: the connexion with the latter is entirely *crossed* (Ferrier and Turner).

From the corpus geniculatum internum there proceeds a tract to the gray cortex of the superior convolution of the temporal lobe. The whole nervous apparatus is thus linked on to the cerebral cortex, and the succession of neurons which build up the entire chain are therefore: (1) the bipolar cells of the ganglion spirale; (2) the neurons of the terminal cochlear nuclei; (3) the neurons of the superior olive and the nucleus of the lateral fillet; (4) the neurons of the corpus geniculatum internum.

It must be borne in mind that all the axons of the cells of the superior olive do not join the trapezoid strand. Many leave its dorsal aspect and pass backwards in a group called the **pedicle of the superior olive**, to end in the nucleus of the sixth nerve, and, through the posterior longitudinal bundle, in the nuclei of the fourth and third nerves. In this way the organ of hearing is brought into connexion with the nuclei, which preside over the movements of the eyeballs (Figs. 403, p. 500, and 420, p. 523).

Central Connexions of the Vestibular Nerve.—Although the central connexions of the vestibular nerve have been closely studied by many observers, they are still very far from being fully understood. The principal nucleus and the nucleus of Deiters both stand in intimate relation with the superior vermis of the cerebellum; and in consideration of the fact that the vestibular nerve is the nerve of equilibration, this is an important and significant circumstance. The strand which establishes this connexion has been termed by Edinger "the direct sensory cerebellar tract," and in all probability it is an efferent tract from the cerebellum. Its fibres arise to a large extent in the cerebellar **roof nuclei** of the opposite side, and, crossing the mesial plane, they sweep forwards around the outer side of the superior cerebellar peduncle as it emerges from the cerebellum to end in the nucleus of Deiters, the chief vestibular nucleus, and very possibly also in the terminal sensory nuclei of certain other cranial nerves, such as the trigeminal, vagus, and glossopharyngeal.

Until the precise nature of the nucleus of Deiters is discovered, the exact character of the central connexions of the vestibular nerve will remain more or less obscure. It cannot be regarded as a nucleus specially given over to the vestibular nerve. Composed of large cells scattered amidst the bundles of the upper part of the descending root of the vestibular nerve, it only becomes a compact nucleus above the level of that nerve, viz. at the point where the restiform body turns backwards into the cerebellum, or, in other words, at the level of the emerging facial nerve and the lower end of the abducent nucleus. Here, in the outer part of the floor of the fourth ventricle, its cells are gathered together in a crowded mass. Deiters himself considered that this nucleus should be regarded as an internode between the cerebellum and the spinal cord, and Ferrier and Turner have brought forward strong evidence in support of this view. Klimoff attaches a very high importance to the direct "sensory" tract of Edinger. From his description it would appear that he regards it as the only cerebellar efferent tract which takes a downward direction. He believes, further, that the axons of the cells of Deiters form the anterior marginal tract of Lowenthal (tractus vestibulo-spinalis of Monakow), which

descends in the antero-lateral column of the cord as far as the lumbar region. It is supposed that the fibres of this tract end in the cord in arborescent terminations around the motor cells in the ventral horn of gray matter.

From what has been said it must be apparent that the nucleus of Deiters plays a most important part in connexion with the maintenance of the equilibrium of the body and the co-ordination of its muscular movements. Thus it constitutes an internode in the path of those fibres which connect the cortex and roof nuclei of the cerebellum with the motor apparatus of the spinal cord; it receives fibres through the vestibular nerve from the labyrinth of the ear; and it sends fibres into the posterior longitudinal bundle, through which it in all probability exercises some influence over the nuclei of the ocular nerves.

Opinion is also divided as to the composition and nature of the so-called descending root of the vestibular nerve. After division of the eighth nerve, Ferrier and Turner were unable to detect any degeneration in this root, and they therefore are inclined to call in question its direct continuity with the nerve. They consider that in all probability it forms an internuncial connexion between the nucleus of Deiters and the cuneate nucleus, in which Bruce has seen its lower end to terminate.

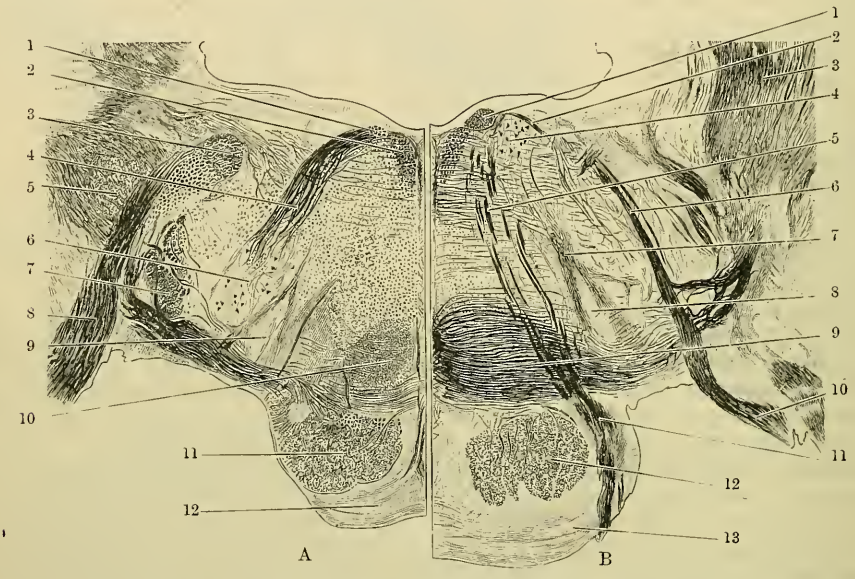


FIG. 419.—SECTION THROUGH THE PONS VAROLII OF THE ORANG,

Showing the nucleus and intrapontine course of the facial nerve. The left side of the drawing is taken from a section at a slightly lower level than the section from which the right side is taken.

A

1. Ascending part of facial nerve.
2. Posterior longitudinal bundle.
3. Descending root of eighth nerve.
4. Radicular fibres of facial nerve.
5. Restiform body.
6. Facial nucleus.
7. Spinal root of fifth nerve.
8. Vestibular nerve.
9. Superior olive.
10. Fillet.
11. Pyramidal tract.
12. Transverse fibres of pons.

B

1. Ascending part of facial nerve.
2. Emergent portion of facial nerve.
3. Restiform body.
4. Nucleus of sixth nerve.
5. Sixth Nerve.
6. Emergent part of facial nerve.
7. Peduncle of superior olive.
8. Superior olive.
9. Corpus trapezoides.
10. Facial nerve.
11. Sixth nerve.
12. Pyramidal tract.
13. Transverse fibres of pons.

Facial Nerve (nervus facialis) (Figs. 419 and 420).—The facial nerve is composed of two distinct parts, viz. a large efferent or motor portion, the **facial nerve proper**, and a small efferent sensory portion termed the **pars intermedia of Wrisberg.** The facial nerve emerges from the brain at the lower border of the pons, immediately in front and to the inner side of the auditory nerve, whilst the pars intermedia sinks into the upper part of the medulla between the facial and auditory nerves. The three nerves, therefore, lie in intimate relation with each other, where they are attached to the surface of the brain, and they pass in company into the internal auditory meatus.

The **nucleus of origin of the facial nerve** is an oval mass of gray matter, about five mm. in length, and containing numerous groups of large multipolar cells. It is sunk deeply in the dorsal or tegmental part of the lower portion of the pons Varolii, and is placed close to the inner side of the spinal root of the fifth nerve. When transverse sections are made through the brain-stem, the facial nucleus is encountered the moment the boundary line between the medulla and pons is passed, and the region immediately above the inferior olivary nucleus is reached. At first it lies so deeply in the tegmentum of the pons that it actually rests upon the dorsal aspect of the corpus trapezoides; but a little farther up the superior olive comes into view, and insinuates itself between the facial nucleus and the trapezial fibres. The upper part of the nucleus is in this way tilted somewhat backwards, and thus comes to lie on the dorsal and outer aspect of the superior olive.

The facial nucleus is situated close to the place where the nerve emerges from the brain, but the nerve does not at once pass to this point of exit. It pursues a long and devious path within the pons before it finally reaches the surface. This intrapontine part of the nerve may be divided into three parts, viz.: (1) a radicular part, (2) an ascending portion, and (3) an emergent part.

The **radicular part of the facial nerve** (Fig. 420) is composed of a large number of fine loosely-arranged bundles of fibres, which issue from the outer and dorsal aspect of the nucleus and proceed backwards and slightly inwards through the pons. Reaching the floor of the fourth ventricle they curve inwards, and the bundles which lie highest up sweep over the outer and dorsal aspect of the lower part of the nucleus of the sixth nerve. Close to the mesial plane they turn sharply upwards and are collected into a single solid nerve-bundle, which constitutes the **ascending part of the facial nerve** (Figs. 419 and 420). This proceeds vertically upwards immediately beneath the ependyma of the ventricular floor, on the dorsal aspect of the posterior longitudinal bundle, and along the inner side of the sixth or abducent nucleus for a distance of about five millimetres. Suddenly the nerve bends outwards at a right angle, and curves a second time over the dorsal aspect of the sixth or abducent nucleus. The nerve now passes straight to the place of exit from the brain, and this part of the intrapontine trunk may be termed the emergent portion (Figs. 419 and 420). The facial nerve thus forms a curved loop over the dorsal aspect of the abducent nucleus. The **emergent part** of the nerve takes an oblique course through the pons to reach the surface. It inclines outwards and downwards as it proceeds towards the ventral aspect of the pons, and on its way it passes between its own nucleus and the spinal root of the fifth nerve.

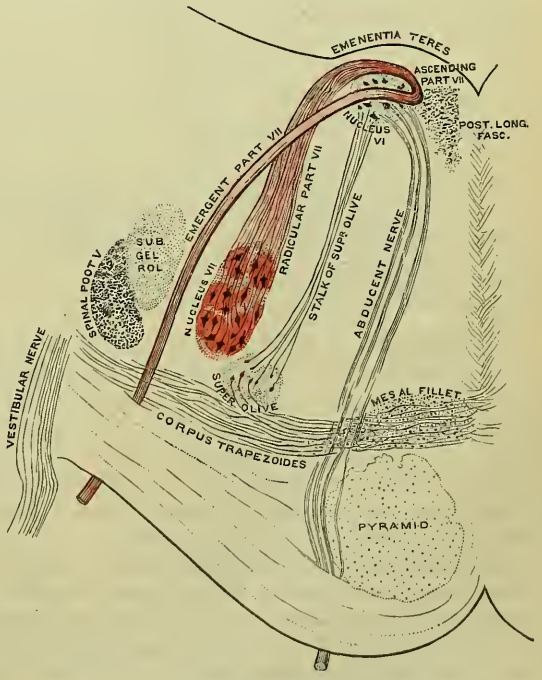


FIG. 420.—DIAGRAM OF THE INTRAPONTINE COURSE PURSUED BY THE FACIAL NERVE.

Entering the facial nucleus, and ending in fine terminal arborisations around its cells, are many fibres from the opposite pyramidal tract; fibres from the spinal root of the fifth nerve; fibres from the corpus trapezoides, etc. The nucleus is thus brought into connexion with the motor area of the cerebral cortex, with the trigeminal nerve or sensory nerve of the face, and with the auditory nerve, etc.

The fibres of the **pars intermedia of Wrisberg** arise from the cells of the geniculate ganglion of the facial nerve. These, like the cells of a spinal ganglion, are unipolar, the single process in each case dividing into a peripheral and a central branch. The group of peripheral fibres represent the chorda tympani branch of the facial nerve, whilst the central fibres form the pars intermedia. The latter penetrate the brain, and, passing either through or on the dorsal side of the spinal root of the fifth nerve, they finally reach the upper part of the column of gray matter in connexion with the fasciculus solitarius, and in this they end. The pars intermedia presents, therefore, the same terminal connexions within the brain as the glossopharyngeal nerve.

Efferent secretory fibres are also described as being present in the pars intermedia. These are said to spring from cells which constitute a *salivary nucleus* placed in the pons on the dorsal aspect of the facial nucleus.

Abducent or Sixth Nerve (nervus abducens) (Figs. 419 and 420).—This is a small motor nerve which emerges from the brain at the lower border of the pons on the outer side of the pyramid of the medulla. It is the nerve of supply to the external rectus muscle of the eyeball. Its nucleus of origin is a small spherical mass of gray matter, containing large multipolar cells, which lies in the dorsal part of the tegmental portion of the pons, close to the mesial plane and immediately subjacent to the gray matter of the floor of the fourth ventricle. Its position can be easily indicated on the ventricular floor, seeing that it is placed subjacent to the emenentia teres and immediately above the level of the striæ acusticæ. Its peculiar and intimate relation to the intrapontine portion of the facial nerve has already been indicated. It lies on the ventral aspect of, and within the concavity formed by, the two limbs of the loop of that nerve.

The axons of the multipolar cells of this nucleus emerge from the inner aspect of the nucleus in the form of several bundles, which proceed through the whole antero-posterior thickness of the pons towards the place of exit. As they pass forwards they incline downwards and slightly outwards. In the tegmental part of the pons they proceed forwards on the inner side of the superior olive, whilst in the ventral part of the pons they keep for the most part to the outer side of the pyramidal bundles, although several of the nerve fasciculi pierce these on their way to the surface.

It would appear probable that certain of the axons of the cells of the abducent nucleus enter the posterior longitudinal fasciculus and proceed upwards in it to join the third or oculomotor nerve of the opposite side. Further mention of these will be made later on. Fibres and collaterals from the pyramidal tract of the opposite side enter the nucleus, and, ending around the cells, bring the nucleus into connexion with the motor area of the cerebral cortex. The pedicle of the superior olive ends partly within the nucleus of the abducent nerve (p. 521).

Trigeminal or Fifth Nerve (nervus trigeminus).—The trigeminal nerve strikes its roots deeply into the brain and establishes a connexion with it which extends from the upper part of the mesencephalon above to the level of the second cervical nerve below. No other cranial nerve presents so extensive a connexion (Fig. 417, p. 518). It is composed of two roots—a large afferent or sensory root and a small efferent or motor root. Both roots appear close together on the surface of the pons, rather nearer its upper border than its lower border, and in the same line as the facial and auditory nerves.

The **sensory root of the fifth nerve** is composed of fibres which arise outside the brain from the cells of the Gasserian ganglion. They end within the brain in two nuclei of termination. One of these is situated in the pons and is termed the sensory nucleus of the trigeminal nerve, and the other is a long column of gray matter which is directly continuous below with the substantia gelatinosa Rolandi of the spinal cord.

The **sensory nucleus** (Fig. 421) is an oval mass of gray matter which is placed half-way up the pons in the outer part of its tegmental portion. It lies close to the outer surface of the pons and immediately subjacent to the ventral submerged margin of the superior cerebellar peduncle. It is directly continuous with the substantia gelatinosa Rolandi, and may be regarded as being merely the enlarged upper end of that column of gray matter.

The fibres of the sensory root of the fifth nerve, on reaching the sensory nucleus, divide in a manner similar to the fibres of the entering posterior roots of the spinal nerves into a system of ascending and descending branches (Fig. 417, p. 518). The ascending fibres are short, and almost immediately enter the sensory nucleus and end within it; the descending fibres turn sharply downwards and form the **spinal root** (tractus spinalis: the ascending root of many text-books). This root descends on the outer side of the column of gray matter formed by the substantia gelatinosa Rolandi, which constitutes its terminal nucleus. Fibres constantly leave it to enter the nucleus, so that the lower it gets the smaller does the spinal root become until, in the upper part of the spinal cord, about the level of the first or second spinal nerve, it disappears altogether.

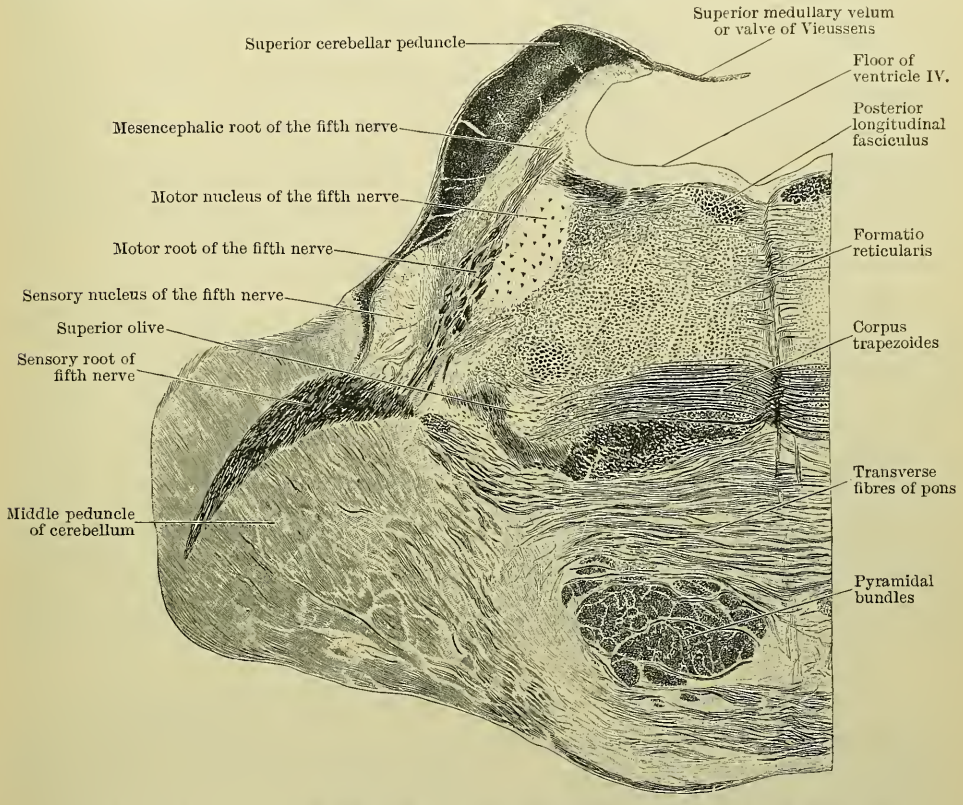


FIG. 421.—SECTION THROUGH THE PONS VAROLII OF THE ORANG, AT THE LEVEL OF THE NUCLEI OF THE TRIGEMINAL NERVE.

The large spinal root of the fifth nerve is a conspicuous object in sections through the pons and medulla. In the former it traverses the tegmental part, first, between the emergent part of the facial nerve and the vestibular nerve; and then lower down, between the restiform body and the nucleus of the facial nerve (Fig. 419, A, p. 522). In cross sections it presents a well-defined semilunar or curved pyriform outline. In the upper part of the medulla it lies on the ventral aspect of the restiform body, and therefore nearer to the surface (Fig. 398, p. 495). Here it is traversed and broken up into separate bundles by the cerebello-olivary fibres and the roots of the glossopharyngeal and vagus nerves. Finally, it comes to the surface and its fibres are spread over the area on the side of the medulla known as the tubercle and funiculus of Rolando (Fig. 394, p. 492).

The small **motor part of the trigeminal nerve** is chiefly distributed to the muscles of mastication, and derives its fibres from two sources, viz. from the motor nucleus and from the mesencephalic root of the trigeminal nerve.

The **motor nucleus** (Fig. 421) lies in the lateral part of the tegmental portion of the pons, close to the inner side of the sensory terminal nucleus, but somewhat

nearer to the floor of the fourth ventricle. It is not placed in the exact line of the facial nucleus, as it is situated somewhat nearer the dorsal aspect of the pons; but, nevertheless, it may be considered as being equivalent in this region to the detached head of the anterior horn of gray matter in the lower part of the medulla. The cells of this nucleus are large and multipolar, and their axons run together to form the greater portion of the motor root of the fifth nerve.

The **mesencephalic root** takes origin in the mesencephalon from a column of large loosely-arranged cells which are placed in the extreme lateral part of the gray matter which surrounds the Sylvian aqueduct. As the lower end of this column of cells reaches the pontine part of the floor of the fourth ventricle it becomes continuous with the dark cells of the locus cœruleus. The mesencephalic root as it is traced downwards gradually gains strength by the addition of new fibres, and it assumes a crescentic form in transverse section (Figs. 430, p. 535; 432, p. 537; 407, p. 505; 406, p. 504). In the lower part of the mesencephalon it lies on the inner side of the superior cerebellar peduncle; and the fourth nerve, on its way to the surface, runs downwards in its concavity and on its mesial aspect. In the upper part of the pons, it continues its course downwards on the outer and deep aspect of the gray matter which forms the floor of the fourth ventricle, and here it stands in relation to the cells of the locus cœruleus. Finally, reaching the level of the nuclei of the trigeminal nerve, the fibres of the mesencephalic root turn forwards and join the motor part of the trigeminal nerve (Fig. 421).

S. Ramon y Cajal has shown that an intimate relationship is established between the mesencephalic nucleus and the principal motor nucleus of the trigeminal nerve. Large numbers of collaterals from the fibres of the mesencephalic root enter the latter nucleus and break up into close networks around its cells. It has been suggested that through this connexion a weak impulse proceeding from the higher nucleus may be transformed within the lower or principal nucleus into a powerful excitation.

(1) It is not known to what parts the fibres of the mesencephalic root go. Kölliker suggests that they supply the tensor veli palatini and the tensor tympani; perhaps, also, they may be distributed to the mylo-hyoid and the anterior belly of the digastric. (2) Fibres from the opposite pyramidal tract go to the motor nucleus and bring it into connexion with the motor area of the cerebral cortex. (3) By degeneration methods the root of the fifth nerve has been traced down to the level of the second cervical nerve (Ferrier and Turner). (4) The axons of the terminal nuclei emerge as arcuate fibres, and, proceeding through the raphe, assume a longitudinal course in the tegmentum of the opposite side, and thus establish connexions with parts higher up (tractus quinto-thalamicus). (5) Some of the axons of the cells of the terminal nucleus enter the motor nucleus, and thus establish a simple reflex apparatus.

The Development of the Parts derived from the Rhombencephalon.

A general sketch of the development of the medulla, pons, and cerebellum has already been given (p. 476). It is only necessary, therefore, in this section to call attention to some of the more important details connected with the process.

Medulla.—In the embryo the cervical flexure indicates in a sharp and definite manner the point of junction between the cord and the brain (Fig. 382, p. 477). In the early condition of the rhombencephalon the calamus scriptorius extends downwards to this level, so that, in the first instance, there is no part of the medulla which corresponds to the closed portion present in the adult. The lower closed part of the medulla makes its appearance at a later period, and is termed by His the **intercalated portion** (Schaltstück).

In our study of the development of that part of the neural tube which forms the spinal cord we have recognised two thick lateral walls connected in front and behind by narrow mid-ventral and mid-dorsal laminæ. The same parts are seen in the developing medulla. Owing, however, to the expansion of the cavity in this portion of the tube the mid-dorsal lamina is stretched out into an extensive and thin epithelial membrane which forms the dorsal wall or roof of the ventricle in this section of the early brain. The thick lateral walls have also fallen away from each other, and are joined in front by the narrow mid-ventral lamina. On section, therefore, the medullary part of the neural tube presents a triangular figure—the base, which is directed backwards, being formed by the thin epithelial expansion derived from the mid-dorsal lamina, the apex by the narrow mid-ventral lamina, and the sides by the thick lateral walls of the tube. Further, each lateral wall consists of an alar or dorsal and a basal or ventral lamina. This subdivision is more clearly indicated than in the cord, and on the inner surface of the lateral wall a strongly-marked longitudinal furrow marks the line of junction of the two laminæ. The histo-

logical development of these several parts of the wall of the medullary portion of the neural tube proceeds in a manner very similar to that already detailed in the case of the cord. No neuroblasts are formed in the mid-ventral and mid-dorsal laminæ; the entire neuroblastic formation is confined to the basal and alar laminæ. Within the basal lamina, likewise, are collected the neuroblasts which form the nuclei of origin of the efferent nerves; whilst within the alar lamina are developed the neuroblasts which constitute the nuclei of termination for the fibres of the afferent nerves.

As development proceeds, the two laminæ of the lateral wall fall outwards to a still greater extent, so that they come to lie very nearly in the same horizontal plane. In this manner their originally mesial or ventricular surfaces come to form the floor of the fourth ventricle. Even in the adult the groove, which separates the basal and alar laminæ so clearly from each other in the early condition, is more or less distinctly perceptible on the ventricular floor. It is represented by the fovea inferior and by the fovea superior. Between these depressions and the mesial groove on the floor of the fully-developed fourth ventricle there is an elongated elevation, which, in its lower part, forms the trigonum hypoglossi, above this the eminentia teres, whilst higher up it is continued towards the commencement of the Sylvian aqueduct. This clearly-marked and bulging mesial strip of the ventricular floor corresponds to the basal lamina, whilst the part of the floor which lies to the outer side of it and the two foveæ is derived from the alar lamina. The latter, therefore, includes the trigonum vagi, the area acustica, and the locus cœruleus.

The further development of the medulla takes place on the ventral aspect of the two laminæ by the deposition of new parts on those which are already formed. An oval bundle of longitudinal fibres makes its appearance on the outer surface of the alar lamina, at the point where this joins the basal lamina. This is the early fasciculus solitarius. It is composed of afferent fibres from the glossopharyngeal and vagus nerves. These, on reaching the surface of the medulla, turn downwards upon it. At first the connexion of the fasciculus solitarius with the medulla is very loose, and it may be regarded as being in the equivalent in this part of the neural tube of the oval bundle of longitudinal fibres which, in the early cord, constitutes the first stage of the column of Burdach. Throughout the further stages of development the fasciculus solitarius indicates in a sufficiently clear manner the point of junction between the alar and basal laminæ. Very soon it becomes covered over by parts developed on its ventral aspect, and it ultimately comes to lie deeply in the substance of the medulla. This change in the position of the fasciculus solitarius with reference to the surface is associated with a striking developmental process which leads to certain remarkable results, and which is termed the formation of the **rhombic lip** of His (Fig. 422, B and C). Before the alar lamina falls outwards, while it still stands erect and its inner surface faces the corresponding surface of the opposite lamina, its dorsal edge is folded outwards and becomes fused with the outer surface of the remaining portion of the alar lamina. This

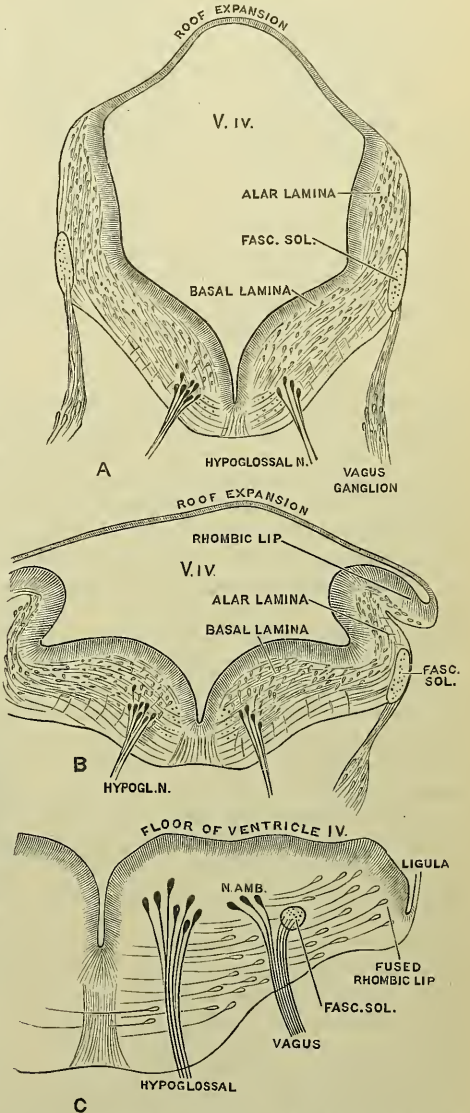


FIG. 422.—THREE STAGES IN THE DEVELOPMENT OF THE MEDULLA OBLONGATA (from His—slightly modified).

is the rhombic lip, and, when the fusion is complete, a multitude of neuroblasts take form within it and migrate in a forward and inwards direction into the ventral parts of the alar and basal laminæ. The mid-ventral lamina—which consists of spongioblastic cells alone, and which forms a narrow partition between the two basal laminæ—is reached on either side by the axons of many of these migrating cells. Whilst acting as an impassable barrier to the neuroblasts, this spongioblastic septum gives free passage from one side to the other to their axons, and a decussation of arcuate fibres in the mesial plane results. In this way the raphe of the medulla is formed. The process is very similar to that which takes place in the course of the formation of the anterior commissure of the cord, of which the raphe may be regarded as the equivalent in the medulla.

The development of the inferior olivary nucleus and of its two accessory parts is likewise closely connected with the migration of the neuroblasts from the region of the rhombic lip. Many of these cells collect together so as to form a nuclear lamella, which afterwards assumes its characteristic crumpled form.

As the neuroblasts of the rhombic lip stream inwards they pass both on the dorsal and the ventral aspects of the fasciculus solitarius, which thus comes to be covered over and separated from the surface. The spinal root of the trigeminal nerve, like the fasciculus solitarius, is also, in the first instance, throughout its entire course on the surface of the medulla, and its change of position in the greater part of its course within the pons and medulla is due to the subsequent development of those parts which cover it over.

The importance of the rhombic lip in the development of the medulla will be better appreciated if we enumerate the parts which spring from it: (1) the inferior olivary nuclei; (2) the cuneate nucleus; (3) the substantia gelatinosa Rolandi; (4) the arcuate nucleus; (5) the internal arcuate fibres; (6) the olivary system of fibres; (7) the restiform body. From this it is evident that the formation of the rhombic lip constitutes an extremely important step in the development of the human brain. Recent investigation, however, makes it clear that in most of the lower mammals the rhombic lip does not attain anything like the degree of prominence which it presents in the early brain of man.

The pyramidal tracts which come down from the cerebral cortex are late in making their appearance in the medulla. The formatio reticularis precedes them in development. They appear in the fourth month of fœtal life, and as they are developed the antero-median furrow between them takes form on the ventral aspect of the medulla.

His has pointed out that the earliest formed part of the medulla is the floor of the fourth ventricle, and that the other parts, speaking generally, are added in succession as we pass towards the surface. "The oldest layer of the medulla is the floor of the fourth ventricle with its nuclei. It is followed, in the first instance, by the reticular formation, and afterwards by the layer containing the olivary and other nuclei. Last of all come the pyramids and the outer (superficial) arcuate fibres" (His).

Pons Varolii.—The information which we possess at the present moment regarding the development of the pons Varolii is somewhat deficient; but there is little doubt that the course pursued is, in general, very similar to that which has been described for the medulla. It has been seen to be composed of parts which are in a great measure equivalent to those met with in the medulla, the formatio reticularis of the latter passing into the tegmental substance in the former, while the pyramids and arcuate nuclei and anterior superficial arcuate fibres of the medulla are represented by the large ventral part of the pons. Further, as His points out, similar relations between the chronological and local succession of layers may be recognised. Thus the primitive position of the motor nucleus of the trigeminal nerve, and also of its spinal root, is a superficial one, and it is only by a later process of development that the nucleus pontis and the thick layer of transverse and longitudinal fibres are formed.

From the phylogenetic point of view the tegmentum is the oldest part of the pons. The study of the comparative anatomy of the brain makes it evident that the large ventral part is comparatively a recent acquisition. As the cerebral cortex extends with the increasing evolution of the cerebral hemispheres (pallium), the ventral part of the pons is seen to keep pace with it in its development. This should easily be understood from what has been said in regard to its structure and connexions. It is composed of the nucleus pontis, the transverse fibres, and the pyramidal and cortico-pontine fibres, all of which stand in direct relation to the cerebral cortex. One of the striking features of the brain of a microcephalic idiot, where the cerebral cortex is greatly reduced, is the corresponding marked diminution in the size of the ventral part of the pons.

Cerebellum.—The roof of the fourth ventricle is formed for the most part by the thin epithelial layer already described as being formed by the expanded mid-dorsal lamina.

This does not stretch, however, over its entire extent. As we approach the upper part of the ventricle, it is seen to become continuous in the region of the isthmus with a thicker lamella. This lamella is bounded *above* by the intercrossing of the two trochlear nerves, which marks on the dorsal aspect of the neural tube the place of junction between the rhombencephalon and the mesencephalon; *below*, it is limited by a forwardly-directed semilunar fold of the thin epithelial ventricular roof, which takes place into the ventricular cavity at the level of the pontine flexure of the brain. The fold so constituted is termed the **plica choroidea**, seeing that mesoderm is introduced between its two layers, and this ultimately gives rise to the choroid plexus of the fourth ventricle (Fig. 425, A). The lamella which forms the roof or dorsal wall of the ventricle in front of the plica choroidea is developed into the cerebellum, and the superior medullary velum (valve of Vieussens).

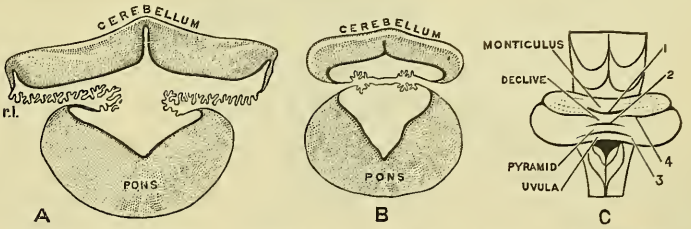


Fig. 423.—Drawings to illustrate the Development of the Cerebellum (from Kuithan).

A. Transverse section through the forepart of the cerebellum of a sheep embryo.
B. Transverse section through the hinder part of the cerebellum of a sheep embryo.
C. Cerebellum of a human fœtus 17 cm. long.

1. Sulcus primarius.
2. Sulcus suprapyramidalis.
3. Sulcus infrapyramidalis.
4. Fissura post-lunata.

r.l. Lateral recess ventricle IV.

The cerebellar part of this lamella consists of two thick lateral plates which meet in the middle line and are joined there by an extremely thin dorsal seam or lamina (Fig. 423, A). The inner extremities of the two cerebellar plates are thus separated by a median groove, which opens into the cavity of the hind-brain (fourth ventricle). The statement, therefore, that the median lobe or vermis of the cerebellum is the most archaic part of the organ and is the part which is developed first is not supported by fact; indeed, the reverse of this is the case, because at this early stage the lateral portions are alone represented.

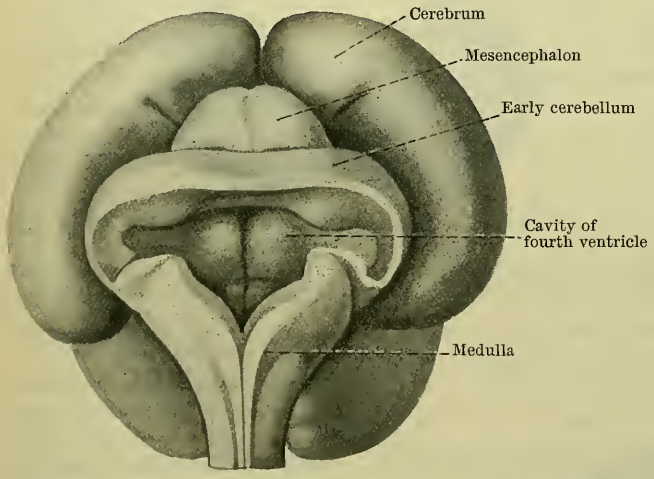


Fig. 424.—The Brain of an Embryo of eleven weeks, viewed from behind to show the development of the cerebellum. At this stage the cerebellum is in the form of a simple band or plate which arches over the hinder aspect of the fore part of the cavity of the hind brain (from His).

In the course of time the inner ends of the cerebellar plates become fused in the middle line, and the median furrow between them disappears. In the process of this fusion the deep part of the intervening furrow remains enclosed within the substance of the median part of the cerebellum and persists for a short time as a minute cerebellar ventricle (Blake).

The cerebellum now presents the appearance of a simple uniform arch which bridges across the dorsal aspect of the upper part of the early fourth ventricle; and very soon the sulci begin to appear. Of late years the development and morphological import of these sulci have received much attention. Stroud, Kuithan, Blake, Elliot Smith, and Bradley have published valuable papers on this subject, and what is written here is largely gathered from the writings of these observers. Further, the terminology suggested by Elliot Smith has been chiefly, but not entirely, followed.

The first fissure to appear is the **floccular fissure**, which cuts off the postero-lateral corner of the cerebellar plate. The portion thus marked off is the **flocculus**, and its early appearance and relatively large size at this stage are significant of its high morphological

importance as a lobule of the cerebellum. The floccular fissure is continued inwards close to the posterior border of the cerebellar plate, joining its fellow of the opposite side in the middle line. Here it receives the name of **post-nodular fissure**. A narrow strip of cerebellar surface is thus marked out. The median part of this strip, by special growth, becomes the **nodulus**, whilst the part which extends between this and the flocculus remains narrow and band-like, and ultimately forms a portion of the inferior medullary velum.

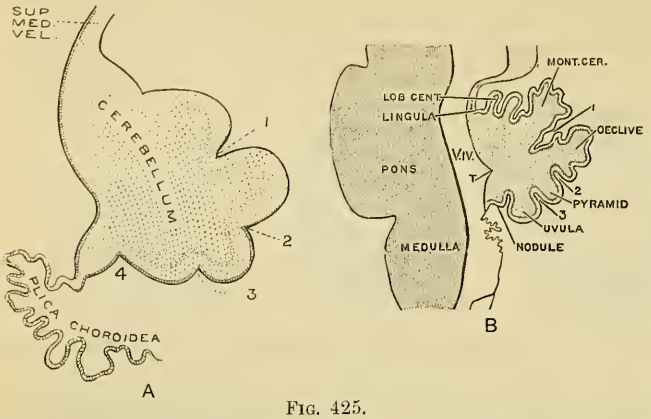


FIG. 425.

A. Mesial section through the cerebellum of an early human fœtus (semi-diagrammatic).
B. Mesial section through the cerebellum of a human fœtus 17 cm. long (from Kuithan).

1. Fissura prima.
2. Fissura suprapyramidalis.
3. Fissura infrapyramidalis.
4. Fissura postnodularis.
T. Transverse groove on the roof of the fourth ventricle.

The next furrow which appears is the **sulcus primarius** (Kuithan) or **fissura prima** (Elliot Smith). It cuts deeply into the vermis in a transverse direction between the culmen monticuli and the clivus monticuli, and is then carried outwards over each hemisphere so as to separate the two crescentic lobules. The fissura prima is the deepest of all the fissures of the vermis, and it is developed towards the end of the third month. A little later two other furrows are observed in the vermis. These are the **suprapyramidal** and the **infrapyramidal** (the fissura secunda of Elliot Smith). By the former the pyramid is limited above; by the latter the pyramid is separated from the uvula.

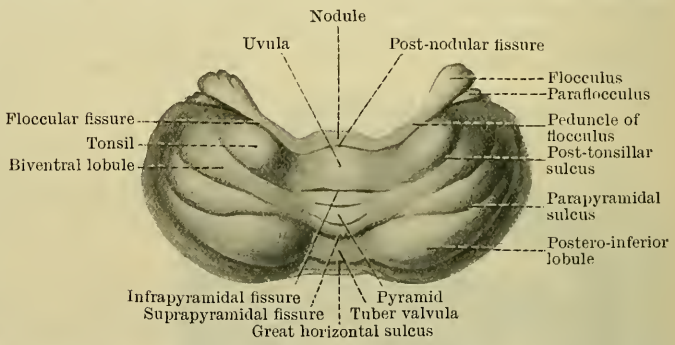


FIG. 426.—UNDER SURFACE OF THE CEREBELLUM OF A HUMAN FŒTUS WHICH HAS REACHED THE END OF THE FIFTH MONTH OF DEVELOPMENT.

After the main fissures of the vermis are established, four important sulci on the surface of each cerebellar hemisphere come into view, viz. the postlunate, the post-tonsillar, the parapyramidal, and the great horizontal sulci.

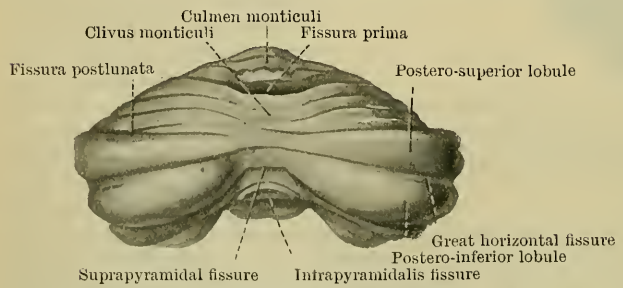


FIG. 427.—CEREBELLUM OF A HUMAN FŒTUS WHICH HAS REACHED THE END OF THE FIFTH MONTH OF DEVELOPMENT. Viewed from above and behind.

The **fissura postlunata** appears in the fourth month, and curves inwards on the upper surface of the organ behind the posterior crescentic lobule. In many cases it becomes confluent with its fellow of the opposite side behind the clivus monticuli. The **post-tonsillar fissure** is seen on the under surface of the cerebellum about the beginning of the fifth month. It circumscribes the prominent and conspicuous tonsil and becomes confluent with the fissura infrapyramidalis. The **parapyramidal fissure** appears on the under surface of the cerebellar hemisphere behind the biventral lobule, and usually joins the suprapyramidal fissure of the inferior vermis.

The **great horizontal fissure**, in spite of its depth in the adult brain—a depth which is due to the excessive growth in the later months of development of the two lobules that bound it—appears very late in the development of the cerebellum. It is first seen as a very broad shallow groove or furrow on the outer margin of the hemisphere. From this it runs forwards to the middle peduncle and backwards towards the vermis, where it usually joins the postlunate fissure. At this stage there is no folium cacuminis, so that the combined portion of the postlunate and great horizontal fissures intervenes between the clivus monticuli and the tuber valvulæ. Even at the time of birth the folium cacuminis is not seen on the surface. It rises up from the bottom of the combined portions of the great horizontal and postlunate fissures so as to form a barrier between them.

Very early a transverse groove appears on the smooth anterior or ventricular surface of the cerebellum (Fig. 425, B, T). This is placed much nearer the lower than the upper border of the organ, and it represents at this stage the angular peak of the tent-like roof of the fourth ventricle in the adult brain. As growth goes on, the portions of the cerebellum in front and behind this groove approach each other, so as to deepen the groove and bring about the backward prolongation of the ventricular cavity towards the cerebellum.

The leading distinctive characters of the human cerebellum are: (1) the small size of the flocculus; (2) the large size of the tonsil; (3) the excessive development of the lateral hemisphere, and particularly of the postero-superior and postero-inferior lobules which bound the great horizontal fissure.

THE MESENCEPHALON.

The mesencephalon or mid-brain is the short, narrow part of the brain-stem which occupies the aperture of the tentorium cerebelli (incisura tentorii), and connects the cerebrum which lies above with the parts which occupy the posterior cranial fossa. It is about three-quarters of an inch in length, and it consists of a dorsal part, composed of the **corpora quadrigemina**, and a much larger ventral part, which is formed by the two **crura cerebri**.

In the undissected brain the corpora quadrigemina are completely hidden from view by the splenium of the corpus callosum, which projects backwards over them, and also by the superimposed cerebral hemispheres. The hinder end of each optic thalamus likewise, to some extent, overhangs the upper part of the mesencephalon on its dorsal and lateral aspect (Fig. 388, p. 482). On this portion of the optic thalamus are seen two projections, which are specially related to the mesencephalon. These are the cushion-like **pulvinar**, which forms the inner and hinder part of the thalamus, and the **corpus geniculatum externum**, an ill-defined oval swelling on the outer and under aspect of the posterior end of the thalamus.

The crura cerebri can to some extent be seen on the base of the brain, where they bound the posterior part of the interpeduncular space. Encircling the upper end of each crus cerebri, where it plunges into the cerebrum, is the optic tract (Fig. 380, p. 474).

The mesencephalon is tunnelled from below upwards by a narrow passage, called the **aqueduct of Sylvius**, which connects the fourth ventricle with the third ventricle (Fig. 429, p. 533). This channel lies much nearer the dorsal than the ventral aspect of the mesencephalon.

Corpora Quadrigemina.—This name is applied to four rounded eminences on the posterior aspect of the mesencephalon (Fig. 388, p. 482). The **superior pair** are larger and broader than the **inferior pair**, but they are not so well defined nor are they so prominent. A longitudinal and a transverse groove separate the quadrigeminal bodies from each other. The longitudinal groove occupies the mesial plane and extends upwards to the posterior commissure of the brain. The upper end of this groove widens out into a shallow depression, in which the **pineal body**, a small conical structure which belongs to the diencephalon, rests. From the lower end of the same groove a short but well-defined and projecting band, the **frenulum veli**, passes to the valve of Vieussens, which lies immediately below the inferior pair of quadrigeminal bodies. The transverse groove curves round below each of the superior pair of quadrigeminal bodies and separates them from the inferior pair. It is also continued in an upward and forward direction on the lateral aspect of the mesencephalon.

The quadrigeminal bodies are not marked off laterally from the sides of the mesencephalon, but each has in connexion with it, on this aspect, a prominent strand of white matter, which is prolonged upwards and forwards under the projecting pulvinar and corpus geniculatum externum. These strands are called the **brachia of the corpora quadrigemina**, and they are separated from each other by a continuation on the side of the mesencephalon of the transverse groove, which intervenes between the two pairs of bodies.

The **corpus geniculatum internum** (corpus geniculatum mediale) is closely associated with the brachia. It is a small, sharply-defined oval eminence, which lies on the side of the upper part of the mesencephalon under shelter of the pulvinar of the optic thalamus.

The **inferior brachium** (brachium quadrigeminum inferius), proceeding upwards from the lower quadrigeminal body, advances towards the corpus geniculatum internum and disappears from view under cover of this prominence. Upon the opposite side of the same geniculate body the mesial root of origin of the optic tract takes shape on the surface, and the appearance is such that the conclusion might very naturally be arrived at that the inferior brachium and this root of the optic tract are continuous with each other under the geniculate elevation. This is not the case, however; the fibres of the inferior brachium, to a large extent, proceed into the subjacent tegmentum under cover of the internal geniculate body and help to constitute an ascending tract from the inferior quadrigeminal body, which proceeds upwards to the optic thalamus. Of the fibres of the mesial root of the optic tract some end in the gray matter of the internal geniculate body, whilst others arise within it. They constitute what is called **Gudden's commissure.**

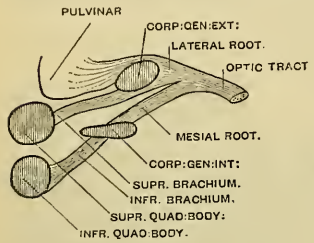


FIG. 428.—DIAGRAM OF THE ROOTS OF THE OPTIC NERVE.

The **superior brachium** (brachium quadrigeminum superius) is carried upwards and forwards between the overhanging pulvinar and the corpus geniculatum internum. A surface examination of the mesencephalon is sufficient to show that, while a large part of this strand enters the corpus geniculatum externum, a considerable portion runs into the lateral root of the optic tract.

The **optic tract** is thus attached to the brain-stem by two roots, viz. a mesial and a lateral, which are separated from each other by a distinct groove. The **mesial root** disappears under the internal geniculate body. The **lateral root** spreads out and some of its fibres enter the superior quadrigeminal body through its brachium, whilst others find their way into the corpus geniculatum externum and the pulvinar of the optic thalamus (Fig. 428).

Crura Cerebri (pedunculi cerebri).—The crura cerebri constitute the chief bulk of the mesencephalon (Fig. 429, p. 533). Upon the basal aspect of the brain they appear as two large rope-like strands, which emerge close together from the upper aspect of the pons Varolii and diverge as they proceed upwards to enter the cerebrum. At the place where each crus disappears into the corresponding side of the cerebrum, it is encircled by the optic tract.

Each crus cerebri is composed of two parts, viz. a **dorsal tegmental part** (tegmentum), which is prolonged upwards into the region below the optic thalamus (subthalamic tegmental region), and a **ventral pedal portion** or **crusta** (basis pedunculi), which, when traced upwards into the cerebrum, is seen to take up a position on the outer side of the optic thalamus and to be continuous with the internal capsule of the brain. When the base of the brain is examined it is the crusta which is seen, and it is observed to be white in colour and streaked in the longitudinal direction. In the tegmentum the longitudinally-arranged fibres are, for the most part, *corticipetal*, or, in other words, fibres which are ascending towards the cortex of the cerebrum; the crusta, on the other hand, is entirely composed of longitudinal strands of fibres which are *corticifugal*, or fibres which descend from the cortex cerebri.

On the surface of the mesencephalon the separation between the tegmental and

pedal portions of the crus cerebri is clearly indicated by an inner and an outer groove. The inner or mesial furrow is the more distinct of the two. It looks into the interpeduncular space, and from it emerge the fascicles of the third or oculo-motor nerve. It is, therefore, termed the **sulcus oculo-motorii** (sulcus nervi oculo-motorii). The outer groove, which is placed on the lateral aspect of the mesencephalon, receives the name of the **sulcus lateralis mesencephali.** When traced downwards, it is observed to become continuous with the furrow which intervenes between the middle and superior peduncles of the cerebellum.

A close inspection of the outer surface of the tegmental part of the crus cerebri, below the level of the quadrigeminal brachia, will reveal some faintly-marked bundles of fibres curving obliquely upwards and backwards to reach the inferior quadrigeminal body (Fig. 390, p. 484). These are fibres of the **lateral fillet**, coming to the surface at the sulcus lateralis and sweeping over the subjacent superior cerebellar peduncle to gain the inferior quadrigeminal body.

INTERNAL STRUCTURE OF THE MESENCEPHALON.

When transverse sections are made through the mesencephalon the aqueduct of Sylvius is seen to be surrounded by a thick layer of gray matter, which receives the name of the **Sylvian gray matter** or the **central gray matter of the aqueduct** (stratum griseum centrale). On the dorsal aspect of the Sylvian gray matter the corpora quadrigemina form a layer which separates it from the surface, and to which the term **lamina quadrigemina** is applied. On the ventral and lateral aspects of the Sylvian gray matter are the tegmental portions of the crura cerebri; whilst, intervening between each of the latter and the corresponding crusta, there is a conspicuous mass of dark pigmented matter termed the **substantia nigra.**

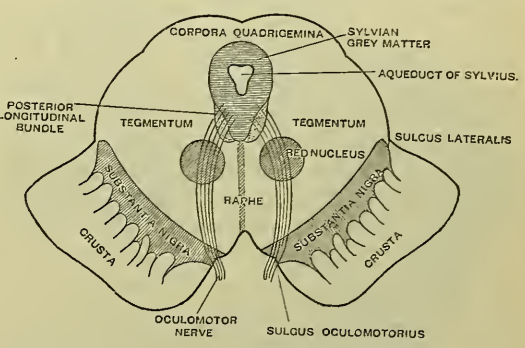


FIG. 429.—DIAGRAMMATIC VIEW OF THE CUT SURFACE OF A TRANSVERSE SECTION THROUGH THE UPPER PART OF THE MESENCEPHALON.

Sylvian Aqueduct and Sylvian Gray Matter (aquæductus cerebri —stratum griseum centrale).—The aqueduct of Sylvius is the canal which leads from the fourth ventricle below, upwards through the mesencephalon, to the third ventricle above. It is not quite three-quarters of an inch in length, and it lies much nearer the dorsal than the ventral surface of the mesencephalon. When examined in transverse section, it presents a triangular outline as it passes into the fourth ventricle and a T-shaped outline close to the third ventricle. In the intermediate part of its course it assumes different outlines, and not always the same form at the same level in different individuals.

The aqueduct of Sylvius is lined by ciliated epithelium, and outside this is the thick layer of Sylvian gray matter, which is directly continuous below with the gray matter spread out on the floor of the fourth ventricle, and above with gray matter on the floor and sides of the third ventricle. Scattered more or less irregularly throughout the Sylvian gray matter are numerous nerve-cells of varying forms and sizes, whilst in addition to these there are three definite collections or clusters of cells, which constitute the nuclei of origin of the trochlear nerve, the oculo-motor nerve, and the mesencephalic root of the trigeminal nerve. The position and relations of these will be given at a later stage.

Substantia Nigra.—When seen in transverse section, the substantia nigra presents a semilunar outline. It consists of a mass of gray matter, in the midst of which are large numbers of deeply pigmented nerve-cells. It is only when this substance is examined in bulk that it appears dark; in thin sections it does not differ much in colour from ordinary gray matter, although, under the microscope, the brown-coloured cells stand out very conspicuously, even under low powers.

The substantia nigra is disposed in the form of a thick layer, interposed between the tegmental and pedal portions of the crus cerebri. It begins below at the upper border of the pons Varolii and extends upwards into the subthalamic region. The margins of this layer of dark-coloured substance come to the surface at the oculo-motor and the lateral sulci of the mesencephalon, and its inner part is traversed by the emerging fascicles of the oculo-motor nerve. It is not equally thick throughout. Towards the lateral sulcus it becomes thin, whilst it thickens considerably near the inner aspect of the crus cerebri. The surface of the substantia nigra, which is turned towards the tegmentum, is concave and uniform; the opposite surface is convex and rendered irregular by the presence of numerous slender prolongations of the substance into the crusta.

The morphological and physiological significance of the substantia nigra is not fully understood, and the connexions established by its cells are imperfectly known.

Inferior Quadrigeminal Bodies (colliculi inferiores).—Each of the inferior quadrigeminal bodies is largely composed of a mass of gray matter which, in transverse section, presents an oval outline (Fig. 432, p. 537). This central nucleus is, to a large extent, encapsulated by white matter. Numerous cells of different sizes are scattered throughout it, and the whole mass is pervaded by an intricate interlacement of fine fibres, which, to a large extent, are derived from the lateral fillet and the inferior brachium.

In transverse sections, through this region, the lateral fillet is seen to abut against the outer margin of the central nucleus. Many of the fibres of this tract enter it at once and become dispersed amongst its cells; others sweep over its dorsal surface, so as to give it a superficial covering; whilst a third group is carried in the form of a thin layer inwards on its ventral aspect, so as to mark it off from the subjacent Sylvian gray matter of the aqueduct (Fig. 432, p. 537). In this manner, therefore, the inferior quadrigeminal nucleus becomes partially circumscribed by the fibres of the lateral fillet. Several of the lateral fillet fibres, which proceed over the superficial or dorsal aspect of the nucleus, reach the mesial plane and form a loose decussation with the corresponding fibres of the opposite side.

The intimate connexion which is thus exhibited between the fibres of the lateral fillet and the nucleus of the inferior quadrigeminal body is very significant. It has already been shown that the lateral fillet, to a large extent, comes from the nuclei of termination of the cochlear nerve of the opposite side, although most of its fibres have to pass through several nuclear internodes before they reach the inferior quadrigeminal body. We must associate, therefore, the inferior quadrigeminal body, and also the corpus geniculatum internum, which likewise receives lateral fillet fibres, with the organ of hearing.

This view of the inferior quadrigeminal bodies is supported both by experimental and by morphological evidence. Speaking broadly, it may be stated that the inferior quadrigeminal bodies are only present as distinct eminences in mammals, and then they are invariably correlated with a spirally-wound and well-developed cochlea. That they have nothing to do with sight, is shown by the fact that, when the eyeballs are extirpated in a young animal, the inferior quadrigeminal bodies remain unaffected, whilst the superior quadrigeminal bodies after a time atrophy (Gudden). When, on the other hand, the cochlear terminal nuclei are destroyed, fibres which have undergone atrophy may be followed to the inferior quadrigeminal bodies of both sides, but particularly to that of the opposite side (Baginski, Bumm, and Ferrier and Turner). A very considerable tract of ascending fibres takes origin within the inferior quadrigeminal body and passes upwards, in the inferior brachium, into the tegmentum subjacent to the internal geniculate body. Within the tegmentum they proceed up to the optic thalamus (Ferrier and Turner).

Superior Quadrigeminal Bodies (colliculi superiores).—The superior quadrigeminal body presents a more complicated structure (Fig. 431). Superficially, it is coated with a very thin layer of white matter, which is termed the **stratum zonale**. Underneath this there is a gray nucleus, called the **stratum cinereum**, which in transverse section exhibits a crescentic outline and rests in a cap-like manner upon the subjacent part of the eminence The succeeding two strata, which respectively receive the names of **stratum opticum** and the **stratum lemnisci**, present this feature in common, that they are composed of gray matter, traversed by numerous fibres. The source from which the fibres are derived differs, however, in each case.

Nerve-fibres reach the superior quadrigeminal body through—(1) the lateral and mesial fillets, and (2) through the superior brachium. The **fillet fibres** enter

the stratum lemnisci, and, in all probability, end there. The **superior brachium** contains fibres of two different kinds, viz. fibres from the optic tract and fibres from the cortex of the occipital lobe of the cerebrum. By the former it is connected with the retina, and by the latter with the visual centre in the occipital region of the cerebral cortex. The *retinal fibres*, for the most part, spread out on the surface of the quadrigeminal body and form the stratum zonale. Most of them dip down into the substance of the body and end in connexion with the cells of the deeper layers; several, however, are carried across the mesial plane, to end in the superior quadrigeminal body of the opposite side. The *occipital fibres*, and probably also some of the retinal fibres, enter the stratum opticum. The fibres from the occipital cortex form part of the optic radiation, and the course which they pursue will be dealt with later on.

Tegmental Portions of the Crura Cerebri (tegmenta).—The tegmentum of the crus cerebri may be regarded as the continuation upwards of the formatio reticularis of the medulla and the dorsal or tegmental portion of the pons into the mesencephalon. It therefore consists of fine bundles of longitudinal fibres intersected by arching fibres, which take a transverse and curved course. The interstices between these nerve-bundles is occupied by gray matter containing irregularly scattered nerve-cells. On its dorsal aspect the tegmentum is continuous, at the side of the Sylvian gray matter, with the bases of the corpora quadrigemina, whilst ventrally it is separated from the crusta by the substantia nigra. The two tegmenta of opposite sides are, to some extent, marked off from each other in the mesial plane by a prolongation upwards of the median raphe of the pons and medulla, although, in the lower part of the mesencephalon, this is much obscured by the decussation of the superior peduncles of the cerebellum. The two longitudinal strands, termed the **posterior longitudinal bundle** and the **fillet**, are prolonged upwards throughout the entire length of the mesencephalon; and they present the same relations to the tegmentum as in the lower parts of the brain. The former is placed in relation to its dorsal aspect, whilst the fillet is carried up in its ventral part.

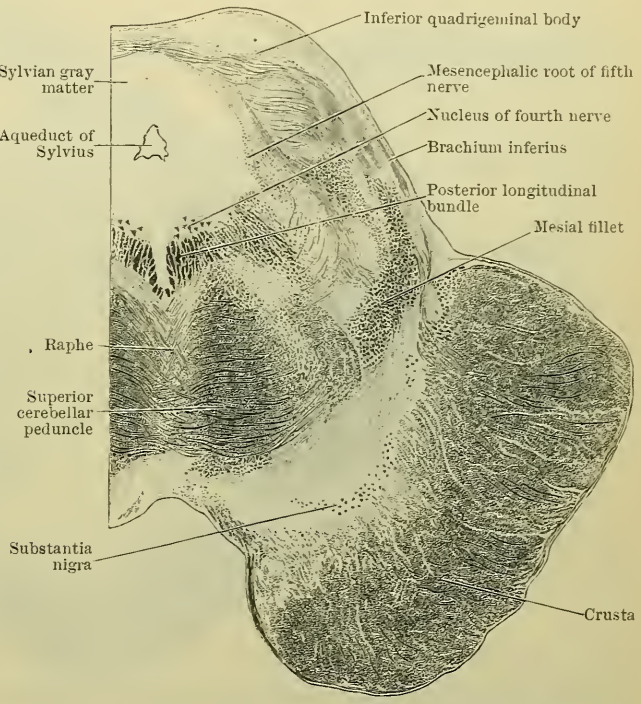


FIG. 430.—TRANSVERSE SECTION THROUGH THE HUMAN MESENCEPHALON AT THE LEVEL OF THE INFERIOR QUADRIGEMINAL BODY.

The tegmentum of the crus cerebri may be considered as presenting two parts: viz. (1) a lower part, which is placed subjacent to the inferior quadrigeminal bodies and which is largely occupied by the decussation of the superior cerebellar peduncles (Fig. 430); and (2) a superior part, subjacent to the superior quadrigeminal bodies, which is traversed by the emerging bundles of the third nerve and which contains a large and striking nuclear mass, termed the nucleus ruber or the red tegmental nucleus (Fig. 431). In the lower part of the mesencephalon is the nucleus of the fourth nerve; in the upper part, the nucleus of the third nerve.

Superior Cerebellar Peduncles (brachia conjunctiva).—As the superior cere-

bellar peduncles leave the pons and sink into the tegmenta of the mesencephalon, they undergo a complete decussation subjacent to the inferior quadrigeminal bodies and the Sylvian gray matter (Figs. 407, p. 505; 432, p. 537; and 430, p. 535). In this manner each peduncle is transferred from one side, across the mesial plane, to the opposite side. The decussation is completed at the level of the upper borders of the inferior quadrigeminal bodies, and then each peduncle proceeds upwards into the superior part of the tegmentum, where it encounters the red nucleus. Into this a large proportion of its fibres plunge and come to an end in connexion with the nuclear cells. Many of the peduncular fibres, however, are carried around the nucleus so as to form for it a capsule which is thicker on the inner than on the outer side (Fig. 431). These are prolonged into the subthalamic region, and ultimately penetrate the ventral aspect of the optic thala-

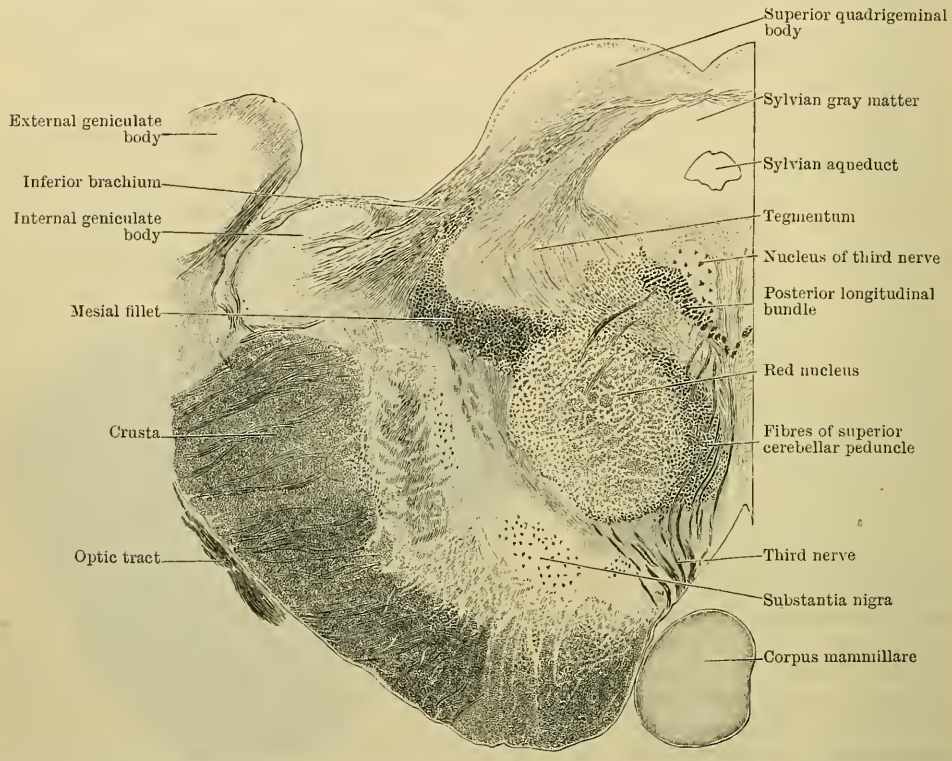


FIG. 431.—TRANSVERSE SECTION THROUGH THE HUMAN MESENCEPHALON AT THE LEVEL OF THE SUPERIOR QUADRIGEMINAL BODY.

mus, where they end in connexion with the thalamic cells. The superior cerebellar peduncle is, therefore, a great efferent tract which issues from the lateral hemisphere of the cerebellum, crosses the mesial plane in the lower part of the mesencephalon, and ends in the red nucleus and the ventral part of the optic thalamus.

Red Nucleus (nucleus ruber).—This is a rounded nuclear mass, of a reddish tint in the fresh brain, which lies in the upper part of the tegmentum, and in the path of the superior cerebellar peduncle. In transverse section it presents a circular outline. It begins at the level of the lower border of the superior quadrigeminal body and it extends upwards into the subthalamic tegmental region. At first it is small and is placed at a little distance from the mesial plane; but as it proceeds towards the subthalamic region, it increases in bulk and approaches more nearly to the mesial raphe, and its neighbour of the opposite side. The curved emerging bundles of the third nerve pass through it on their way to the surface. The relation which the fibres of the opposite superior cerebellar peduncle present to it has been described. These fibres traverse its lower part in such numbers that in Weigert-Pal specimens it presents a very dark colour; but higher up, as the fibres

are gradually absorbed by the nuclear mass, they become less numerous in its midst, and the nucleus assumes a paler tint.

Numerous fibres which descend from the cerebral cortex and others from the corpus striatum enter the red nucleus. It likewise sends out fibres which proceed in two directions: (1) upwards into the thalamus; (2) downwards to the spinal cord. The former may be regarded as carrying on the continuity of the superior cerebellar path after its internodal interruption in the red nucleus. The fibres to the spinal cord, called the *rubro-spinal tract* and first described by Monakow, cross to the opposite side and then descend in the tegmentum to reach the lateral column of the cord.

Posterior Longitudinal Fasciculus.—This is a very conspicuous tract of longitudinal fibres which extends throughout the whole length of the medulla, pons, and mesencephalon, in the formatio reticularis or tegmental part of each. Below, at the level of the decussation of the pyramids, it becomes continuous with the anterior basis-bundle of the spinal cord (p. 491), whilst, by its opposite or upper end, it establishes intricate connexions in the region immediately above the mesencephalon. Throughout its whole length it lies close to the mesial plane and its fellow of the opposite side. In the mesencephalon it is applied to the ventral aspect of the Sylvian gray matter, whilst in the pons and medulla it is situated immediately subjacent to the gray matter of the floor of the fourth ventricle. One of its most salient features is the intimate association which it presents with the three motor nuclei from which the nerves for the supply of the muscles of the eyeball take origin, viz. the oculo-motor or third nucleus, the trochlear or fourth nucleus, and the abducent or sixth nucleus. The first two of these are closely applied to its inner and dorsal aspect, whilst the abducent nucleus is placed on its outer side. Into each of these nuclei it sends many collaterals, and probably also some of its constituent fibres, and these end in terminal arborisations around the nuclear cells. It would appear, therefore, that one of the most important functions of this strand is to bind together these nuclei, and thus enable them to act in harmony with each other. Fibres also enter the posterior longitudinal fasciculus from the auditory system and perhaps, also, from the facial and other motor nuclei. The results obtained by degeneration would seem to indicate that, to a large extent, it is formed of fibres which run a short course within it.

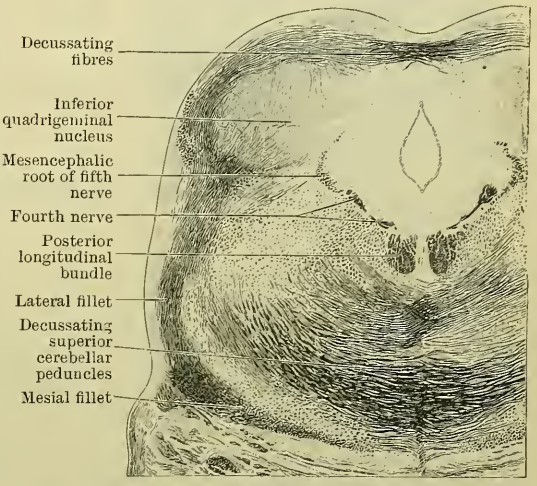


FIG. 432.—SECTION THROUGH THE INFERIOR QUADRIGEMINAL BODY AND THE TEGMENTUM OF THE MESENCEPHALON BELOW THE LEVEL OF THE NUCLEUS OF THE FOURTH NERVE IN THE ORANG. (The decussation of the superior cerebellar peduncles and the course of the fourth nerve in the Sylvian gray matter are seen.)

In spite of the large amount of attention which has been given to the study of the posterior longitudinal bundle, it must be admitted that there is little unanimity of opinion regarding its connexions and functions. That it is a brain tract of high importance, is evident from the fact that it is present in all vertebrates, and, further, that its fibres assume their medullary sheaths at an extremely early period. In fish, amphibians, and reptiles, it is one of the most powerful bundles of the medulla. In man its fibres medullate between the sixth and seventh months of fœtal life, and at the same time as the fibres of the anterior basis-bundle of the cord, with which it stands in connexion.

According to Van Gehuchten and Edinger, it extends upwards beyond the level of the oculo-motor nucleus, and in the subthalamic region its fibres take origin from a special nucleus of its own in the gray matter of the third ventricle, immediately below the level of the corpora mammillaria. Fibres also enter the posterior longitudinal bundle from a nucleus common to it and the posterior commissure of the brain. This nucleus is placed in the fore-part of the Sylvian gray matter of the mid-brain. Held asserts that numerous fibres, arising from cells in the superior quadrigeminal body, curve in an arcuate manner in the tegmentum outside the Sylvian gray

matter, to take part on the ventral aspect of this in what is called the "fountain decussation." Reaching the opposite side these fibres turn downwards and join the posterior longitudinal fasciculus. The same authority considers that fibres from the ventral part of the posterior commissure can also be traced downwards into the posterior longitudinal bundle. Edinger, on the other hand, places these fibres as a distinct tract on the ventral and lateral aspect of the posterior longitudinal bundle, although in apposition with it.

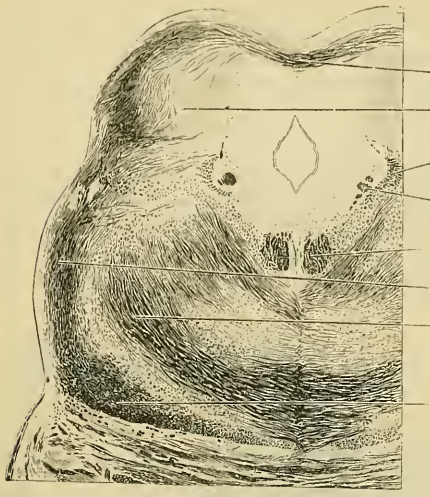


FIG. 433.—SECTION THROUGH THE INFERIOR QUADRIGEMINAL BODY AND THE TEGMENTUM OF THE MESENCEPHALON, AT A SLIGHTLY LOWER LEVEL THAN FIG. 432.

Mendel believes that fibres from the oculo-motor nucleus are carried down in the posterior longitudinal bundle, and, from this, into the facial nerve for the supply of the orbicularis palpebrarum and the corrugator supercilii, bringing these muscles therefore under the control of the same nucleus as the levator palpebræ superioris muscle. This view has received corroboration at the hands of Tooth and Turner. It has been further suggested that fibres from the hypoglossal nucleus may, by the posterior longitudinal fasciculus, reach the facial nerve, and through it the orbicularis oris. In this manner the same nucleus would hold sway over the tongue and the sphincter muscle of the lips. The close relation which exists between the ascending part of the intrapontine portion of the facial nerve and the posterior longitudinal bundle would render the passage of fibres from one to the other a matter which could easily be understood. Another interchange of fibres through the posterior longitudinal bundle has been described by Duval and Laborde. According to these authorities, fibres from the abducent nucleus ascend in the posterior longitudinal bundle into the mesencephalon, and establish connexions with that part of the oculo-motor nucleus from which the nerve for the internal rectus of the opposite side derives its fibres. If this view be correct, it affords a ready and simple anatomical explanation of the harmonious action of the external and internal recti muscles in producing movements of the two eyeballs simultaneously to the right and to the left. From the investigations of E. H. Fraser it would appear that no fibres from the abducent nucleus go directly into the oculo-motor nerve. The same observer has shown that many fibres from Deiters' nucleus, through the path afforded by the posterior longitudinal bundle, enter the third and the fourth nuclei.

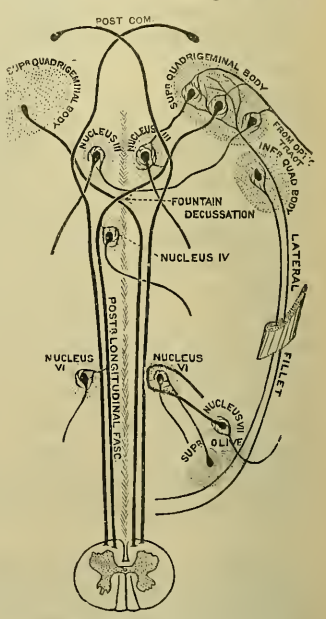


FIG. 434.—DIAGRAM OF THE CONNEXIONS OF THE POSTERIOR LONGITUDINAL BUNDLE (after Held—modified).

Lateral Fillet (lemniscus lateralis).—The lateral fillet is a definite tract of longitudinal fibres, which extends upwards through the lateral part of the tegmental substance of the upper portion of the pons and the mesencephalon. It is formed by the fibres of the corpus trapezoides in the lower part of the pons, abruptly turning upwards and taking a course towards the quadrigeminal region. Entering into its constitution, therefore, are fibres from several sources, viz. (1) from the terminal cochlear nuclei of the opposite side; (2) from the terminal cochlear nuclei of the same side; (3) from the superior olivary nuclei. As the tract proceeds upwards a continuation of the gray matter of the superior olivary nucleus is carried up in connexion with it to form the nucleus of the lateral fillet, and from this fibres are also added to the strand. In the mesencephalon the fibres of the lateral fillet end in the nucleus of the inferior quadrigeminal body (p. 534) and in the gray substance of the corpus geniculatum internum, whilst a few are carried into the superior quadrigeminal body. The fibres which go to the inferior quadrigeminal body sweep outwards round the outer side of the superior cere-

bellar peduncle, and to some extent appear on the surface of the mesencephalon (p. 533).

But the lateral fillet cannot be considered as a tract composed entirely of ascending fibres belonging to the auditory system. It also contains descending fibres, the connexions and functions of which are not fully understood. These have been traced by Ferrier and Turner through the pons and medulla into the lateral column of the cord.

Mesial Fillet (lemniscus mesialis).—The mesial fillet has already been followed through the medulla and pons, and its position in each of these portions of the brain-stem has been defined (pp. 493 and 504). In the tegmentum of the lower part of the mesencephalon it is carried up in the form of a more or less flattened band on the ventral aspect of the decussating superior cerebellar peduncles. To its outer side, and forming an angle with it (as seen in transverse section), is the lateral fillet (Figs. 432 and 433), and at this level there is no clear demarcation between these two tracts. In the upper part of the mesencephalon the appearance of the red nucleus in the tegmentum causes the mesial fillet to take up a more lateral and dorsal position, so that it now comes to lie subjacent to the corpus geniculatum internum (Fig. 431, p. 536). At this level it exhibits a crescentic outline in transverse section, and the lateral fillet has to a large extent disappeared from its outer side.

The mesial fillet takes origin in the lower part of the medulla oblongata from the gracile and cuneate nuclei of the opposite side (p. 493). Seeing that the posterior column of the cord ends in these nuclei, the fillet may be considered to continue that column upwards into the brain. In the mesencephalon a considerable contribution of fibres is given by the mesial fillet to the superior quadrigeminal body, and then the remainder of the tract proceeds through the subthalamic tegmental region into the hinder part of the lateral nucleus of the optic thalamus. Here its fibres end in terminal arborisations around the thalamic cells.

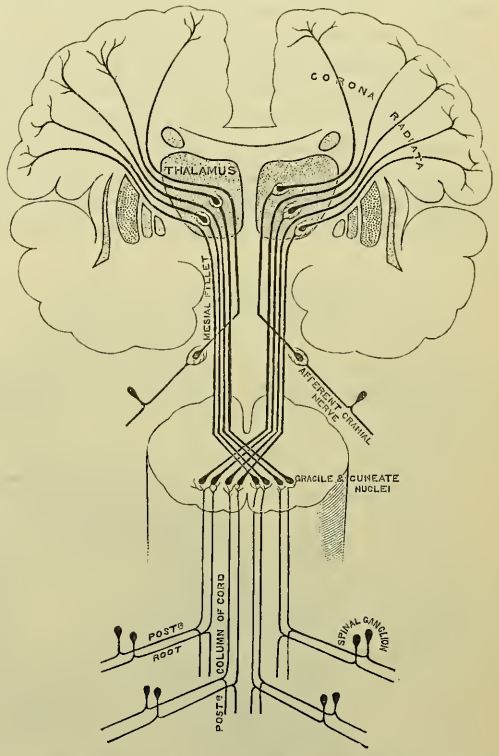


FIG. 435.—DIAGRAM OF THE CONNEXIONS OF THE MESIAL FILLET AND ALSO OF CERTAIN OF THE THALAMO-CORTICAL FIBRES.

Ganglion Interpedunculare and Fasciculus Retroflexus.—On the ventral aspect of the tegmentum, close to the surface and to the mesial plane, there is a small group of cells in the lower part of the gray matter which forms the locus perforatus posticus. This is termed the *ganglion interpedunculare.*

The *fasciculus retroflexus* is a small band of fibres which arises above in the ganglion habenulae—a nuclear mass which will be studied in connexion with the diencephalon—and which runs downwards and forwards in the tegmentum of the upper part of the mesencephalon between the inner aspect of the nucleus ruber and the mesial plane, to end in the ganglion interpedunculare.

Fountain Decussation.—If the region in front of the posterior longitudinal bundles be examined in the upper part of the mesencephalon a very close decussation of fibres in the mesial plane will be observed in the interval between the two red nuclei. This is the "fountain decussation." According to Held, the fibres which take part in the dorsal portion of the fountain decussation (decussation of Meynert) come from the superior quadrigeminal bodies, and, after they have gained the opposite side, they turn downwards in the posterior longitudinal fasciculus. The ventral part of the decussation (decussation of Forel) would appear to be formed by arcuate fibres of the tegmentum which arise in the gray matter of the Sylvian aqueduct.

Crusta or Pes of the Crus Cerebri (basis pedunculi).—The crusta presents a

somewhat crescentic outline when seen in section, and it stands quite apart from its fellow of the opposite side. It is composed of a compact mass of longitudinally directed fibres, all of which, as Déjerine has shown, arise in the cortex of the cerebrum and pursue an unbroken corticifugal course into and through the crusta of the crus cerebri. These fibres may be classified into two distinct sets, viz. cortico-pontine and pyramidal.

The **cortico-pontine fibres** possess this leading peculiarity: in their course downwards they are all arrested in the ventral part of the pons Varolii and end in fine terminal arborisations around the cells of the nucleus pontis. They come from certain well-defined areas of cerebral cortex, viz. (1) the cortex of the prefrontal part of the frontal lobe, and (2) the cortex of the middle portion of the temporal lobe. These tracts would appear to hold a very definite position within the crus. Thus it has been satisfactorily established that the *temporo-pontine strand* forms the outer or lateral fifth of the crusta, whilst the researches of Ferrier and Turner render it more than likely that the *fronto-pontine strand* holds a similar position in the inner or mesial part of the crusta.

The **pyramidal fibres** constitute the great motor tract from the cerebral cortex. They occupy a position corresponding to the middle three-fifths of the crusta. The pyramidal tract differs from the cortico-pontine strands in being carried downwards through the ventral part of the pons and on the ventral aspect of the medulla into the cord, which it enters in the form of the crossed and direct pyramidal tracts. On its way through the pons and medulla it sends fibres to the various motor nuclei in those sections of the brain-stem.

Deep Origin of the Cranial Nerves which arise within the Mesencephalon.

Two of the motor cranial nerves, viz. the oculo-motor and the trochlear nerves, as well as the mesencephalic root of the trigeminal nerve, obtain origin within the mesencephalon. The nuclei from which they spring are all situated within the gray matter of the Sylvian aqueduct.

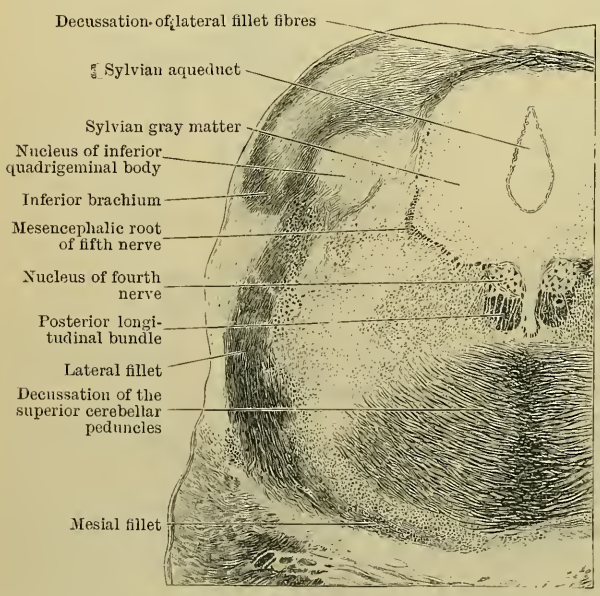


Fig. 436.—Section through the Inferior Quadrigeminal Body and the Tegmentum of the Mesencephalon at the Level of the Middle Part of the Nucleus of the Trochlear Nerve (Orang).

Mesencephalic Root of the Trigeminal Nerve (radix descendens).—The fibres of this root arise from a column of large, sparsely-arranged cells, which extends throughout the entire length of the mesencephalon. These cells lie in the outer part of the Sylvian gray matter, close to the tegmentum. The axons which emerge from the cells run downwards close to the outer surface of the Sylvian gray matter in the form of a small, gradually-increasing tract. In the lower part of the mesencephalon this tract assumes a crescentic outline, and ultimately comes to lie on the inner aspect of the superior cerebellar peduncle (Fig. 406, p. 504). The further course of the mesencephalic root of the fifth nerve through the upper part of the pons, to the point where it joins the emerging motor root of the trigeminal nerve, has already been traced (p. 526).

Trochlear or Fourth Nerve (nervus trochlearis).—The trochlear nerve supplies

the superior oblique muscle of the eyeball. It emerges from the brain, on its dorsal aspect, at the upper part of the superior medullary velum, immediately below the lower border of the inferior quadrigeminal body (Fig. 438, p 543). The nucleus from which it arises is a small oval mass of gray matter, placed in the ventral part of the Sylvian gray matter at the level of the upper part of the inferior quadrigeminal body. The close association of this nucleus with the posterior longitudinal bundle has already been alluded to. It is sunk deeply in a bay, which is hollowed out on the dorsal and inner aspect of that tract. The nerve has a course of some length within the mesencephalon. The axons of the cells leave the outer aspect of the nuclear mass, and curve backwards and outwards in the Sylvian gray matter until they reach the concave inner surface of the mesencephalic root of the trigeminal nerve. Here they are gathered together into one or two round bundles, which, bending sharply, turn downwards at a right angle and descend on the inner side of the trigeminal root. When the region below the inferior quadrigeminal body is reached, the nerve makes another sharp bend. This time it turns inwards, enters the upper end of the superior medullary velum, in which it decussates with its fellow of the opposite side. Having thus crossed the mesial plane, the trochlear nerve emerges at the inner border of the superior cerebellar peduncle. The course pursued by the fourth nerve within the Sylvian gray matter may be traced by examining in succession Fig. 437; Fig. 432, p. 537; Fig. 433, p. 538; and Fig. 407, p. 505.

Oculo-motor or Third Nerve (nervus oculo-motorius).—The oculo-motor nerve supplies the levator palpebræ superioris, all the ocular muscles, with the exception of the superior oblique and the external rectus, and also two muscles within the eyeball, viz. the sphincter iridis and the musculus ciliaris. The nucleus of origin is placed in the ventral part of the Sylvian gray matter subjacent to the superior quadrigeminal body (Fig. 431, p. 536). In length it measures from 5 to 6 mm. Its lower end is partially continuous with the nucleus of the trochlear nerve, whilst its upper end extends upwards for a short distance beyond the mesencephalon into the gray matter on the lateral wall of the third ventricle. Its relation to the posterior longitudinal bundle is even more intimate than that of the trochlear nucleus. It is closely applied to the dorsal and inner aspect of this strand; many of its cells occupy a position in the intervals between the nerve-bundles of the tract, and some even are seen on its ventral or tegmental aspect. The axons of the nuclear cells leave the nucleus in numerous bundles, which describe a series of curves as they proceed forwards through the posterior longitudinal bundle, the tegmentum, red nucleus, and inner margin of the substantia nigra, to finally emerge from the brain-stem along the bottom of the sulcus oculo-motorius on the inner aspect of the crus cerebri.

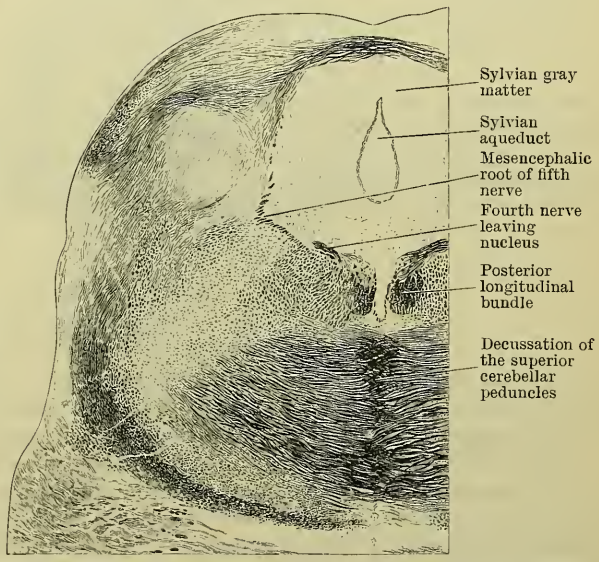


Fig. 437.—Section through the Inferior Quadrigeminal Body and the Tegmentum of the Mesencephalon at the Level of the Lower Part of the Nucleus of the Trochlear Nerve (Orang).

The cells of the oculo-motor nucleus are not uniformly distributed throughout it. They are grouped into several more or less distinct collections or clumps, some of which possess cells which differ in size and appearance from the others. These cell-clusters are very generally believed to possess a definite relation to the several branches of the nerve and the muscles which they supply. Perlia recognises no less than seven such cell-clusters in each nucleus, with a small

median nucleus placed accurately on the middle line, and from which fibres for both nerves spring. Whilst the majority of the fibres in the oculo-motor nerve arise from the cell-groups which lie on its own side of the mesial plane, it has been satisfactorily established that a certain proportion of its fibres are derived from the nucleus of the opposite side, thus forming a crossed connexion and giving rise to a median decussation. These crossed fibres are supposed by some to supply the internal rectus muscle; and we have seen that there is reason to believe that the part of the nucleus from which these fibres are derived stands in connexion through the posterior longitudinal fasciculus with the abducent or sixth nucleus from which proceeds the nerve of supply for the external rectus muscle. The harmonious action of the internal and external recti in producing the conjugate movements of the eyeballs is thus explained.

The oculo-motor nucleus is connected—(1) with the occipital part of the cerebral cortex by fibres which reach it through the optic radiation; (2) with the trochlear and abducent nuclei (and probably with other nuclei) by fibres which come to it through the posterior longitudinal bundle; (3) possibly with the facial nerve by fibres which pass out from it into the posterior longitudinal bundle (p. 538); (4) with the visual system by fibres which enter it from the cells of the superior quadrigeminal body.

Development of the Mesencephalon.

Even in the early embryo the mesencephalon constitutes the smallest section of the brain-tube, although the disproportion in size between it and the other primitive subdivisions of the brain is not nearly so marked as in the adult. Owing to the cephalic flexure, the mid-brain for a time occupies the highest part of the summit of the head. Later on it becomes completely covered over by the expanding cerebral hemispheres.

The corpora quadrigemina are derived from the alar laminæ of the lateral walls of the brain-tube, whilst the basal laminæ thicken and ultimately form the tegmenta and crustæ of the two crura cerebri. The original cavity of the mid-brain is retained as the aqueduct of Sylvius.

For a considerable time the cavity of the mesencephalon remains relatively large, and the lower part of its dorsal wall is carried downwards in the form of a diverticulum or recess, which overlaps the cerebellar plate. About this time, also, the dorsal wall shows a median fold or ridge. Both of these conditions are transitory. As the corpora quadrigemina take shape, the median ridge disappears and is replaced by the median longitudinal groove, which separates the quadrigeminal bodies. Only its lower part is retained, and this is represented by the frenulum veli of the adult brain. The diverticulum of the cavity gradually becomes reduced, and finally disappears as the aqueduct assumes form.

FORE-BRAIN.

Parts derived from the Diencephalon.

Under this heading we have to consider: (1) the **thalamus**; (2) the **epithalamus**, which comprises the pineal body and the habenular region; (3) the **metathalamus**, or the corpora geniculata; and (4) the **hypothalamus.**

The hypothalamus consists of two portions, viz. the **pars mammillaris hypothalami**, which comprises the corpus mammillare and the portion of the central gray matter which forms the floor of the third ventricle in its immediate vicinity; and the **pars optica hypothalami**, which embraces the tuber cinereum, the infundibulum, the pituitary body, and the lamina cinerea. Strictly speaking, the optic part of the hypothalamus does not belong to the diencephalon, but it is convenient to study the parts which it represents at this stage. It is also convenient to examine, at the same time, the **subthalamic tegmental region**, although a very considerable part of this is apparently developed in connexion with the mesencephalon.

The original cavity of that part of the brain-tube which forms the diencephalon is represented by the greater part of the third ventricle of the brain.

Optic Thalamus (thalamus).—The optic thalamus is the principal object in this section of the brain (Fig. 438). It is a large ovoid mass of gray matter, which lies obliquely across the path of the crus cerebri as it ascends into the cerebrum. The smaller anterior end of the thalamus lies close to the mesial plane, and is only separated from the corresponding part of the opposite side by a very narrow interval. The enlarged posterior ends of the two thalami are placed more widely apart, and in the interval between them the corpora quadrigemina are situated. As previously stated, the crusta of the crus cerebri, composed of corticifugal fibres

gradually inclines outwards as it is traced upwards, and thus it assumes a place on the outer aspect of the optic thalamus and passes into the internal capsule of the brain. The tegmental part of the crus, on the other hand, comes into relation with the under surface of the thalamus, and forms in this situation the **subthalamic tegmental region.** To a large extent the longitudinal fibres of the tegmentum are corticipetal. For the most part they enter the thalamus, and end within it in fine arborisations around the thalamic cells.

The two optic thalami, in their anterior two-thirds, lie close together on either side of a deep mesial cleft, which receives the name of the third ventricle of the brain. Each thalamus presents an anterior and a posterior extremity and four surfaces. The inferior and external surfaces are in apposition, and, indeed, directly connected with adjacent parts of the brain, and on this account it is only possible to study them by means of sections through the brain. The superior and internal surfaces are free.

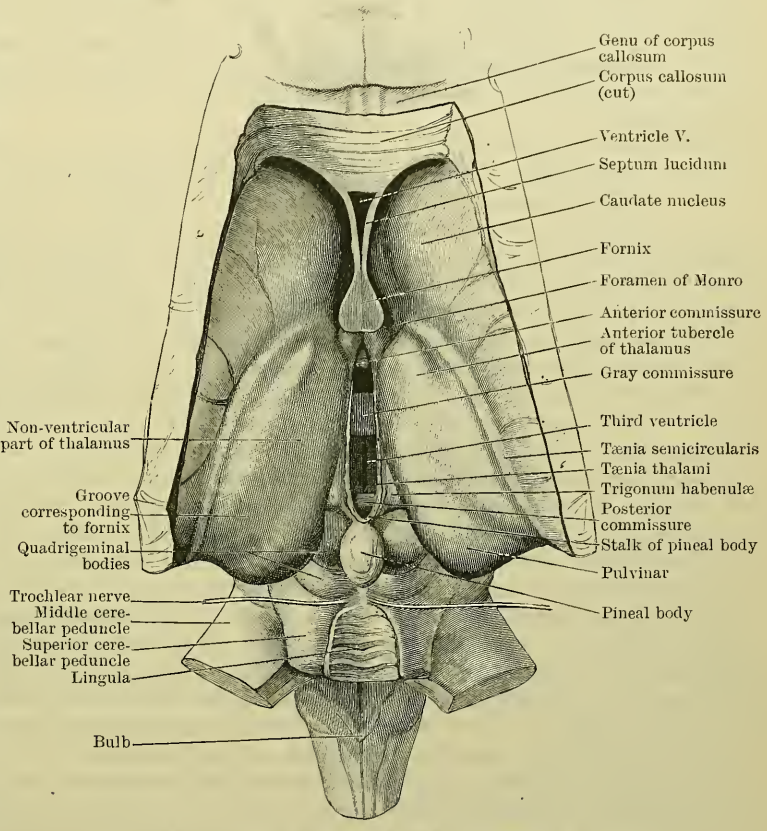


FIG. 438.—THE TWO OPTIC THALAMI (as seen from above).

The *external* or *lateral surface* of the thalamus is applied to a thick layer of white matter interposed between it and the lenticular nucleus, called the **internal capsule**, and composed of fibres passing both upwards towards and downwards from the cerebral cortex. A large proportion of these fibres descend to form the crusta or ventral part of the crus cerebri. From the entire extent of the external surface of the thalamus large numbers of fibres stream out and enter the internal capsule, to reach the cerebral cortex; over the same area other fibres which arise in the cortex of the cerebrum enter the thalamus. Both of these sets of fibres constitute what is termed the **thalamic radiation**, and by this the thalamus establishes a double connexion with the entire extent of the cerebral cortex. As the fibres leave and enter the thalamus they intersect each other at acute angles, and over the whole of the external surface of the ganglionic mass they form a very distinct reticulated zone or stratum, which is termed the **external medullary lamina.**

The *inferior* or *ventral surface* of the thalamus rests chiefly on the subthalamic tegmental region and the corpus mammillare. In front, however, as the tegmental substance gradually disappears, the thalamus comes to lie over the outer part of the tuber cinereum. From the subthalamic region many fibres enter the thalamus on its under aspect, whilst other fibres leave this surface of the thalamus to take part in the thalamic radiation.

The *superior* or *dorsal surface* of the thalamus is free. Externally it is bounded by a groove, which traverses the floor of the lateral ventricle of the brain and intervenes between the thalamus and the caudate nucleus. In this groove are placed a slender band of longitudinal fibres, termed the tænia semicularis, and in its fore-part the vein of the corpus striatum. Internally, the superior surface of the thalamus is separated from the internal or mesial surface in its anterior half by a sharp edge or prominent ledge of the ependyma of the third ventricle. This is termed the **tænia thalami**, and the ridge which it forms is accentuated by the fact that, subjacent to it, there lies a longitudinal strand of fibres called the **stria medullaris**. When these two structures, viz. the ependymal ridge and the subjacent tract, are traced backwards, they are seen to turn inwards and become continuous with the stalk or peduncle of the pineal body. Behind the portion of the tænia thalami which turns inwards towards the pineal body a small depressed triangular area, the **trigonum habenulæ**, situated in front of the superior quadrigeminal body, forms a very definite inner boundary for the hinder part of the superior surface of the thalamus.

The superior surface of the thalamus is slightly bulging or convex, and is of a whitish colour, owing to the presence of a thin superficial covering of nerve-fibres, termed the **stratum zonale**. It is divided into two areas by a faint oblique groove, which begins in front at the inner border, a short distance behind the anterior extremity of the thalamus, and extends outwards and backwards to the outer part of the hinder end. This groove corresponds to the outer edge of the fornix. The two areas which are thus mapped out are very differently related to the ventricles of the brain, and also to the parts which lie above the thalamus. The *outer area*, which includes the anterior extremity of the thalamus, forms a part of the floor of the lateral ventricle. It is covered with ependyma, overlapped by the choroid plexus of this ventricle, and lies immediately subjacent to the corpus callosum. Along the line of the groove the epithelial lining of the lateral ventricle is reflected over the choroid plexus of this cavity. The *inner area*, which includes the hinder end of the thalamus, intervenes between the lateral and third ventricles of the brain, and takes no part in the formation of the walls of either. It is covered by a fold of pia mater, termed the velum interpositum, above which is the fornix, and these two structures intervene between the thalamus and the corpus callosum.

The *anterior extremity* of the thalamus, called the **anterior tubercle** (tuberculum anterius thalami), forms a marked bulging. It projects into the lateral ventricle, behind and to the outer side of the free portion of the anterior pillar of the fornix. The foramen of Monro, a narrow aperture of communication between the lateral and third ventricles of the brain, is bounded in front by the anterior pillar of the fornix and behind by the anterior tubercle of the thalamus.

The *posterior extremity* of the thalamus is very prominent and forms a cushion-like projection, which overhangs the brachia of the corpora quadrigemina. This prominence is called the **pulvinar**. Another oval bulging on the hinder part of the thalamus receives the name of the **corpus geniculatum externum**. It is situated below, and to the outer side of, the pulvinar, and presents a very intimate connexion with the optic tract.

The *mesial surfaces* of the two thalami are placed close together, and are covered not only by the lining ependyma of the third ventricle, but also by a tolerably thick layer of gray matter, continuous below with the central gray substance which surrounds the aqueduct of Sylvius in the mesencephalon. A band of gray matter, termed the **gray** or **soft commissure** (commissura mollis), crosses the third ventricle and joins the inner surfaces of the two thalami together.

Intimate Structure and Connexions of the Optic Thalamus.—The upper surface of the thalamus is covered by the **stratum zonale**, a thin coating of white fibres derived to some extent from the optic tract, and probably also from the optic radiation. The inner surface has a thick coating of central gray matter, whilst intervening between the internal capsule and the outer surface is the **lamina medullaris externa**. The lower surface merges into the subthalamic region.

The gray matter of the optic thalamus is marked off into three very apparent parts—termed the anterior, the mesial, and the lateral thalamic nuclei—by a thin

vertical sheet of white matter, continuous with the stratum zonale, termed the **lamina medullaris interna.** The **lateral nucleus** (nucleus lateralis thalami) is by far the largest of the three. It is placed between the internal and the external medullary laminæ, and it stretches backwards beyond the mesial nucleus, and thus includes the whole of the pulvinar (Fig. 440). The **mesial nucleus** (nucleus medialis thalami) only reaches as far back as the habenular region. It is placed between the central gray matter of the third ventricle and the internal medullary lamina. The lateral nucleus is more extensively pervaded by fibres than the mesial nucleus. From the lateral nucleus by far the greatest number of the fibres which form the **radiatio thalami** pass, and these are seen crossing it in various directions towards the lamina medullaris externa. The **anterior nucleus** (nucleus anterior thalami) is the smallest of the three thalamic nuclei. It forms the prominent anterior tubercle, and is prolonged in a wedge-shaped manner, for a short distance, downwards and backwards between the anterior parts of the mesial and lateral nuclei. The internal medullary lamina splits into two parts and partially encloses the anterior nucleus. In connexion with its large cells a very conspicuous bundle of fibres, the **bundle of Vicq d'Azyr** (fasciculus thalamo-mammillaris), which arises in the corpus mammillare, comes to an end

A diffuse gray mass imperfectly marked off from the under surface of the lateral nucleus receives the name of the *ventral nucleus.* Its lower part is composed of the **central nucleus of Luys** and the **nucleus arcuatus.** In section the former appears as a circular mass of gray matter, which comes into view immediately behind the point where the internal medullary lamina disappears. It would seem to be intimately connected with fibres which reach it from the red nucleus and from the posterior commissure. These fibres pass round it so as to mark it off from the rest of the thalamus, and in front of the nucleus many of them enter the internal medullary lamina. The **nucleus arcuatus** is a small semilunar mass of gray matter placed below and to the outer side of the central nucleus of Luys.

The **connexions of the thalamus** are of an extremely intricate kind. It would appear to be a ganglionic mass interposed between the tegmental corticipetal tracts and the cerebral cortex. In its hinder part, and through its stratum zonale, it also has important connexions with the optic tract. The corticipetal tegmental tracts, which enter it from below, will be noticed in connexion with the subthalamic region. Suffice it to say, for the present, that these fibres end in the midst of the thalamus in connexion with the thalamic cells. In addition to these, enormous numbers of fibres, arising within the thalamus as the axons of its cells, stream out from its outer and under surfaces to form the thalamic radiation. These **thalamo-cortical fibres** pass to every part of the cortex; and although there is no separation of them into distinct groups as they leave the thalamus, it is customary to regard them as constituting a frontal stalk, a parietal stalk, an occipital stalk, and a ventral stalk. But fibres from the cortex, **cortico-thalamic fibres,** likewise stream into the thalamus in large numbers, and end in fine arborisations around its cells. A double connexion with the cerebral cortex is thus established by the thalamus.

The **frontal stalk** of the thalamic radiation emerges from the anterior part of the lateral surface of the thalamus and passes through the anterior limb of the internal capsule, to reach the cortex of the frontal lobe. Many of these fibres end in the caudate and lenticular nuclei, between which they proceed. The **parietal stalk** issues from the lateral surface of the thalamus, and, passing through the internal capsule (and to some extent, also, through the lenticular nucleus and the external capsule), gains the cortex of the hinder part of the frontal lobe and of the parietal lobe. The **occipital stalk** emerges from the outer aspect of the pulvinar and constitutes the so-called optic radiation. These fibres sweep outwards and backwards round the outer side of the posterior horn of the lateral ventricle to gain the cortex of the occipital lobe. The **ventral stalk** streams out from the under aspect of the anterior part of the thalamus, in front of the subthalamic tegmental region and the corpus mammillare. Its fibres arise in both the mesial and lateral nuclei, and sweep downwards and outwards to reach the region below the lenticular nucleus. One very distinct band which lies dorsal to the other fibres (ansa lenticularis) enters the lenticular nucleus, whilst the remainder (ansa peduncularis) continue in an outward direction below the lenticular nucleus and gain the cortex of the temporal lobe and of the insula or island of Reil.

Flechsig divides the thalamo-cortical fibres of ordinary sensation into three sensory systems. These he has been able to distinguish by studying the order in which they assume their sheaths of myelin in the fœtus and infant.

Ferrier and Turner, by the degenerative method of investigation, corroborate Flechsig's results. They confirm the observation of Flechsig that, while thalamic fibres are distributed to

the several regions of the cerebral cortex to an almost equal extent, there is one district, viz. the frontal pole, to which the supply is scanty. Another very important result has been obtained by these authors. They have established the fact that many of the thalamic fibres cross the mesial plane in the corpus callosum, and thus gain the cortex of the opposite cerebral hemisphere. Hamilton's crossed callosal tract thus receives conformation.

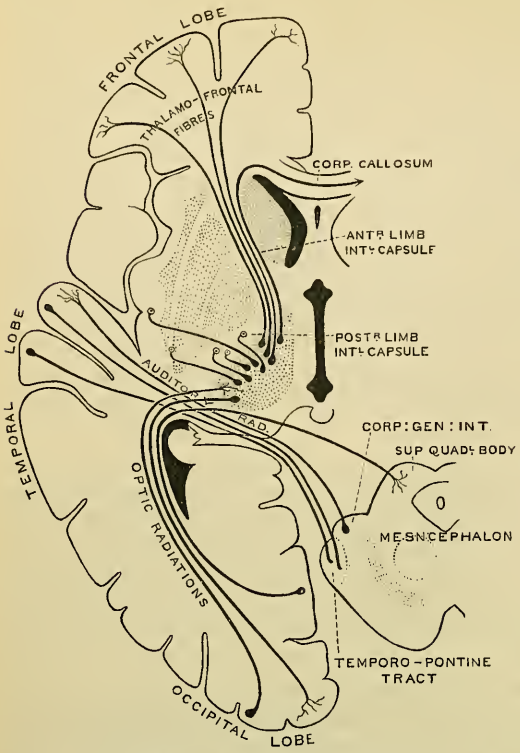


FIG. 439.—SCHEMA. Founded on the observations of Flechsig, and Ferrier and Turner.

Intimate Structure of the Corpus Geniculatum Externum. — Sections through the external geniculate body reveal the fact that it is composed of a series of alternately placed gray and white curved laminæ. This gives it a very characteristic appearance. The white laminæ are composed of fibres which enter the body from the optic tract and the optic radiation. The connexions of the geniculate bodies will be studied with the optic tract.

Subthalamic Tegmental Region. —The tegmental part of the crus cerebri is prolonged upwards and assumes a position below the hinder part of the thalamus. The **red nucleus** is a conspicuous object in sections through the lower part of this region (Fig. 440). It presents the same appearance as lower down in the mesencephalon, and, gradually diminishing, it disappears before the level of the corpus mammillare is reached. Carried up around it are the same longitudinal tracts of fibres which have been studied in relation to it in the tegmental part of the mesencephalon. Certain of these fibres, placed in immediate relation to the red nucleus, form a coating or capsule for it. This coating is partly derived from those fibres of the superior cerebellar peduncle which pass directly up into the thalamus and also partly from fibres which issue from the nucleus itself. The **mesial fillet**, also, which in the upper part of the mesencephalon is observed to take up a position on the lateral and dorsal aspect of the red nucleus, maintains a similar position in the subthalamic region. When the red nucleus comes to an end these various fibres are continued onwards and form, in the position previously occupied by the nucleus, a very evident and dense mass of fibres. The fibres of the mesial fillet, of the superior cerebellar peduncle, and of the red nucleus are prolonged upwards into the ventral part of the thalamus, where they end in connexion with the thalamic cells.

The **substantia nigra** is likewise carried into the subthalamic region, where it maintains its original position on the dorsal aspect of the crusta of the crus cerebri. As it is traced upwards, it is seen to gradually diminish in amount. It shrinks from within outwards, and finally disappears when the hinder part of the corpus mammillare is reached.

In coronal sections through the subthalamic region, the most conspicuous object which comes into view is the **corpus subthalamicum** or the **nucleus of Luys** (Fig. 440). It is a small mass of gray matter, shaped like a biconvex lens, which makes its appearance on the dorsal aspect of the crusta of the crus cerebri immediately to the outer side of the substantia nigra. At first it lies in an angle, which is formed by the meeting of the crusta and the internal capsule; but, rapidly enlarging in an inward direction, it takes the place of the diminishing substantia nigra on the dorsal surface of the crusta at the level of the lower part of the corpus mammillare. The corpus subthalamicum is rendered all the more evident by the fact that it is

sharply defined by a thin capsule of white fibres. On its mesial aspect these fibres proceed inwards and form a very evident decussation across the middle line in the floor of the third ventricle, immediately above the hinder ends of the corpora mammillaria.

The corpus subthalamicum, in the fresh condition, presents a brownish colour, partly from the fact that its cells are pigmented, and partly also on account of the numerous capillary blood-vessels which pervade its substance.

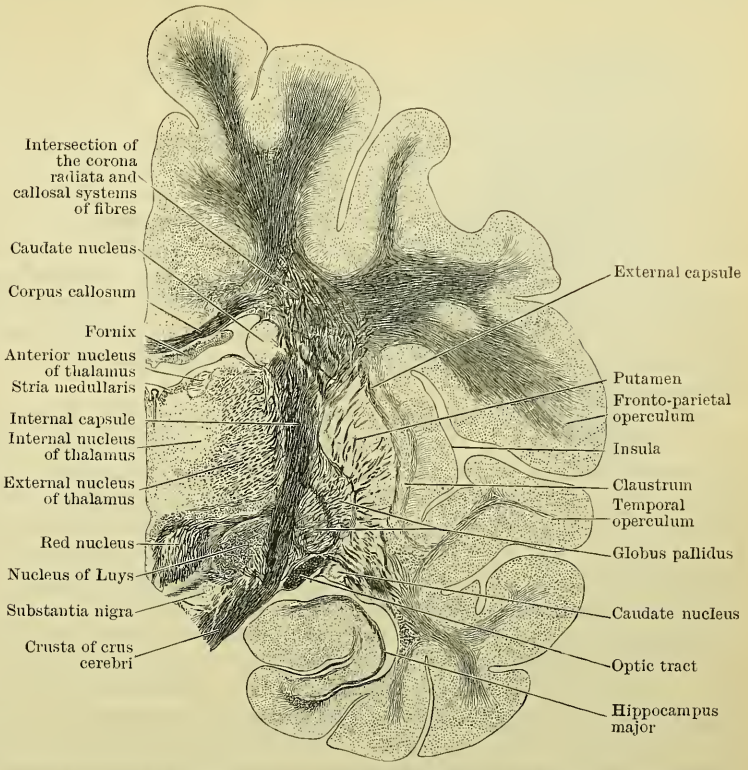


FIG. 440.—CORONAL SECTION THROUGH THE CEREBRUM OF AN ORANG PASSING THROUGH THE SUBTHALAMIC TEGMENTAL REGION.

Pineal Body (corpus pineale).—This is a small, dark, reddish body, about the size of a cherry-stone and shaped after the fashion of a fir-cone. Placed between the hinder ends of the two thalami, it occupies the depression on the dorsal aspect of the mesencephalon, which intervenes between the two superior quadrigeminal bodies. Its base, which is directed upwards, is attached by a hollow stalk or peduncle. This stalk is separated into a dorsal and a ventral part by the prolongation backwards into it of a small pointed recess of the cavity of the third ventricle. The dorsal part of the stalk curves outwards and forwards, and on each optic thalamus becomes continuous with the tænia thalami and the subjacent stria medullaris; the ventral part is folded round a narrow but conspicuous cord-like band of white matter, which crosses the mesial plane immediately above the base of the pineal body and receives the name of the **posterior commissure** of the cerebrum (Fig. 438, p. 543).

The pineal body is not composed of nervous elements. The only nerves in its midst are the sympathetic filaments which enter it, with its blood-vessels. It is composed of spherical and tubular follicles, filled with epithelial cells, and containing a variable amount of gritty, calcareous matter.

The pineal body is a rudimentary structure, but in certain vertebrates it attains a much higher degree of development than in man. In the lizard, blind-worm, etc., it is present in the form of the so-called pineal eye. In structure it resembles, in these animals, an invertebrate eye, and it possesses a long stalk, in which nerve-fibres are developed. Further, it is carried through an aperture in the cranial wall, and consequently lies close to the surface on the dorsum of the head between the parietal bones.

Trigonum Habenulæ.—The small, triangular, depressed area which receives this name is placed immediately in front of the superior quadrigeminal body in the interval between the peduncle of the pineal body and the hinder end of the thalamus (Fig. 438, p. 543). It marks the position of an important collection of nerve-cells, which constitute the **ganglion habenulæ**. The axons of these cells are collected on the ventral aspect of the ganglion into a bundle, called the **fasciculus retroflexus**, which takes a curved course downwards and forwards in the tegmentum of the

mesencephalon. The fasciculus retroflexus lies close to the inner side of the red nucleus, and finally comes to an end in a group of cells termed the **ganglion interpedunculare**, situated in the lower part of the locus perforatus posticus (see p. 539).

The ganglion habenulæ is likewise intimately connected with the stria medullaris and the dorsal part of the stalk of the pineal body.

As previously stated, the **stria medullaris**—a very evident band of white matter—lies on the optic thalamus, subjacent to the ependymal ridge termed the tænia thalami. When traced backwards, many of the fibres of the stria medullaris are observed to end amongst the cells of the ganglion habenulæ, whilst others are continued past the ganglion to enter the peduncle of the pineal body, and, through it, to reach the ganglion habenulæ of the opposite side, in connexion with the cells of which they terminate. The stria medullaris, therefore, ends partly in the ganglion habenulæ of its own side and partly in the corresponding ganglion of the opposite side. The decussation of fibres across the middle line forms the dorsal part of the pineal stalk or peduncle, and is frequently termed the **commissura habenularum.**

When the stria medullaris is traced in the opposite direction, it is noticed to split into a dorsal and ventral part near the anterior pillar of the fornix. The *dorsal part* turns abruptly upwards, and, joining the fornix, is carried in it to the hippocampus major or cornu ammonis from cells in which its fibres take origin. The *ventral part* turns downwards and appears to spring from a collection of cells in the gray matter on the base of the brain close to the optic chiasma. The stria medullaris is believed to form a part of the olfactory apparatus.

Commissura Posterior.—The posterior commissure is a slender band of white matter, which crosses the middle line under cover of the stalk of the pineal body and overlies the entrance of the aqueduct of Sylvius into the third ventricle. The fibres which enter into the formation of the posterior commissure are believed to arise in a special nucleus, which is placed in the central gray matter immediately above the oculo-motor nucleus. They decussate with each other across the mesial plane and thus the commissure is formed. The other connexions of this little band are not satisfactorily established, but Held believes that some of its ventral fibres pass downwards into the posterior longitudinal bundle.

Locus Perforatus Posticus (substantia perforata posterior).—This has already been described on p. 475. Some delicate bands of white matter, termed the **tænia pontis**, may frequently be seen emerging from the gray matter of this region; they then curve round the crura cerebri in close relation to the upper border of the pons, into which they ultimately sink (Fig. 390, p. 484).

Corpora Mammillaria.—The corpora mammillaria are two round white bodies, each about the size of a pea, which lie side by side in the interpeduncular space on the base of the brain, immediately in front of the locus perforatus posticus.

Each corpus mammillare is coated on the outside by white matter derived from the anterior pillar of the fornix, and contains, in its interior, a composite gray nucleus with numerous nerve-cells. Several important strands of fibres are connected with the corpus mammillare: (1) The **anterior pillar of the fornix** curves downwards in the lateral wall of the third ventricle to reach the corpus mammillare, and its fibres end amidst the cells of that body. (2) A bundle of fibres, called the **bundle of Vicq d'Azyr**, which at first sight appears to be continuous with the anterior pillar of the fornix, takes origin in its midst and extends upwards into the optic thalamus, to end in fine arborisations around the large cells in the anterior thalamic nucleus. (3) Another bundle of fibres, the **pedunculus corporis mammillaris**, takes form within the corpus mammillare and extends downwards in the gray matter of the floor of the third ventricle, to reach the tegmentum of the mesencephalon. The ultimate destination of these fibres is doubtful.

Tuber Cinereum and Infundibulum.—The tuber cinereum is a small, slightly prominent field of gray matter, which occupies the anterior part of the interpeduncular space between the corpora mammillaria behind and the optic chiasma in front. From its fore-part the **infundibulum**, or stalk of the pituitary body, projects downwards and connects that body with the base of the brain. In its

upper part the infundibulum is hollow, a small, funnel-shaped diverticulum of the cavity of the third ventricle being prolonged downwards into it.

Pituitary Body (hypophysis).—This is a small oval structure, flattened from above downwards, and with its long axis directed transversely, which occupies the pituitary fossa in the floor of the cranium. It is composed of two lobes—a large anterior lobe and a smaller posterior lobe, which are closely applied the one to the other. The infundibulum, which extends downwards from the tuber cinereum, is attached to the posterior lobe.

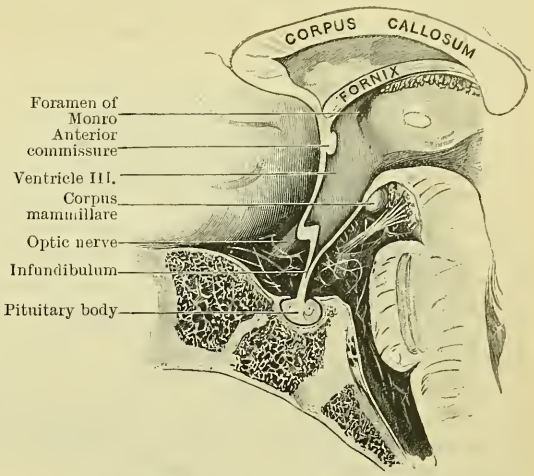


FIG. 441.—MESIAL SECTION THROUGH THE PITUITARY REGION IN A CHILD OF TWELVE MONTHS OLD.

In this section, as well as in the section figured in Fig. 442, the infundibulum has the appearance of being attached to the anterior lobe. This is due to the way in which the larger anterior lobe grows backwards so as to embrace the smaller posterior lobe. The latter is, as it were, accommodated in a hollow in the hinder aspect of the anterior lobe.

From a photograph by Professor Symington.

The infundibulum and posterior lobe of the pituitary body are developed in the form of a hollow diverticulum, which grows downwards from the floor of that part of the embryonic brain which afterwards forms the third ventricle. The original cavity of this diverticulum becomes obliterated, except in the upper part of the infundibulum. In structure, the posterior lobe of the pituitary body shows little trace of its origin from the wall of the brain-tube. It is chiefly composed of connective tissue and blood-vessels, with branched cells scattered throughout it.

The anterior lobe has quite a different origin, and may be regarded as the functional part of the pituitary body. It is derived from a tubular diverticulum, which grows upwards from the primitive buccal cavity or stomodæum. Its connexion with the latter (canalis cranio-pharyngeus) is in the course of time cut off, and the diverticulum becomes encased within the cranial cavity in intimate association with the cerebral portion of the organ. Structurally, it consists of tubules or alveoli, lined by epithelial cells and surrounded by capillary vessels. Its structure is in some respects not unlike that of the parathyroid bodies. In giants, and in cases of acromegaly, the pituitary body is usually greatly enlarged.

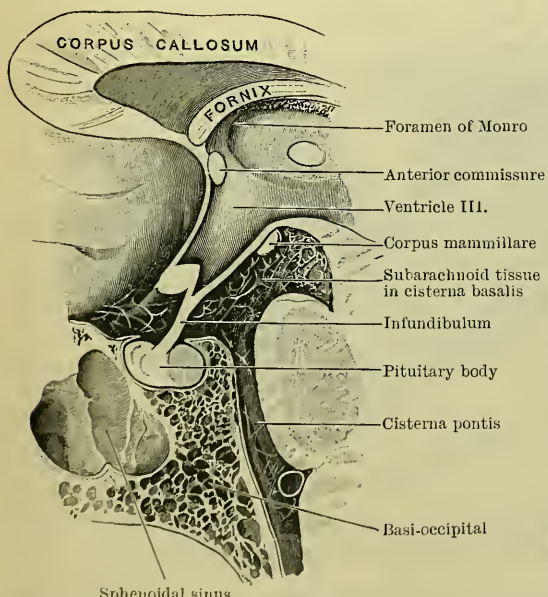


FIG. 442.—MESIAL SECTION THROUGH THE PITUITARY REGION IN THE ADULT.

Lamina Cinerea.—This is a thin, delicate lamina which may be seen on the basal aspect of the brain, stretching from the upper aspect of the optic chiasma in an upward direction to become connected with the rostrum of the corpus callosum.

Anterior Commissure of the Cerebrum.—In the anterior part of the cleft, between the two optic thalami and immediately in front of the anterior pillars of the fornix, a round bundle of fibres crosses the mesial plane. This is the anterior commissure. It is much larger than the posterior commissure.

Third Ventricle (ventriculus tertius). — This is the narrow cleft which separates the two optic thalami. Its depth rapidly increases from behind forwards, and it may be said to extend from the pineal body behind to the lamina cinerea in front. Its *floor* is formed by the structures already studied within the area of the interpeduncular space on the base of the brain, viz. the tuber cinereum, the corpora mammillaria, the gray matter of the locus perforatus posticus, and also to some extent behind this by the tegmenta of the crura cerebri. It is interesting to note that the central gray matter which surrounds the Sylvian aqueduct is directly continuous with the gray matter of the locus perforatus posticus and tuber cinereum, and in this way it comes to the surface in the base of the brain. The optic chiasma crosses the floor in front and marks the place where the latter becomes continuous with the anterior wall of the cavity. The *front wall* of the third ventricle is formed by the lamina cinerea, which extends upwards from the optic chiasma. The anterior commissure, as it crosses from one side to the other, projects into the ventricle, but of course it is excluded from the cavity by the ventricular epithelial lining. It may be taken as indicating the place where the roof joins the anterior wall. The *roof* of the third ventricle is formed by a thin epithelial layer, continuous with the thin epithelial lining of the cavity, which stretches across the mesial plane from one tænia thalami to the other. Applied to the upper surface of the epithelial roof is the fold of pia mater, termed the velum interpositum, and the roof is invaginated into the cavity along its whole length by two delicate choroid plexuses, which hang down from the under surface of this fold. When the velum interpositum is removed the thin epithelial roof is torn away with it, leaving only the lines of attachment in the shape of the tænia thalami.

The *lateral wall* of the third ventricle is formed for the greater part of its extent by the inner surface of the optic thalamus, covered by a thick layer of

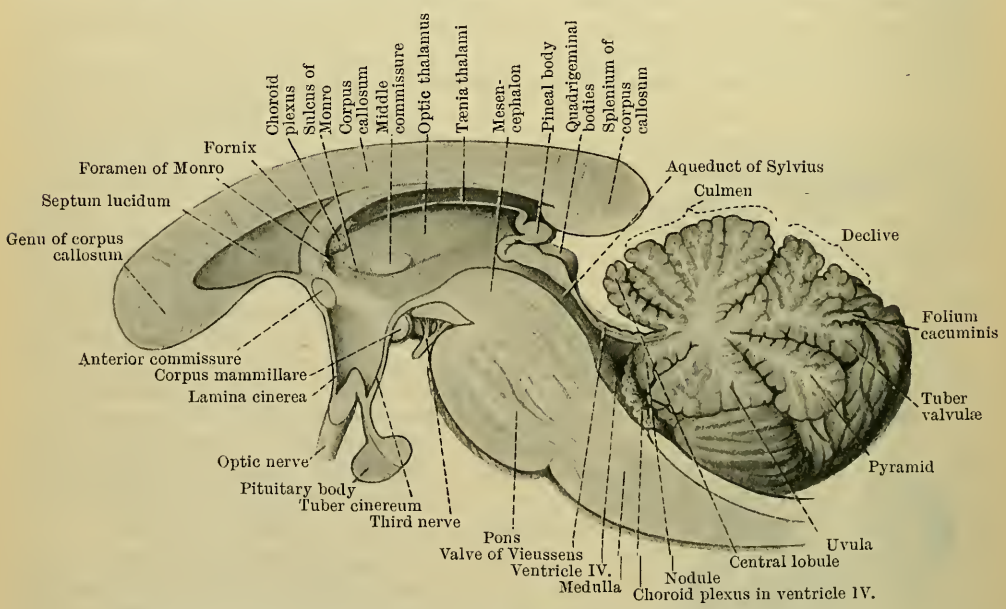


Fig. 443.—Mesial Section through the Corpus Callosum, Diencephalon, etc.
Shows the third and fourth ventricles connected by the aqueduct of Sylvius.

central gray matter continuous with the Sylvian gray matter of the mesencephalon. A little in front of the middle of the ventricle the cavity is crossed by the **middle or soft commissure**, which connects the thalami with each other, and in front of this the anterior pillar of the fornix is seen curving downwards and backwards in the lateral wall. At first the bulging which it forms is distinctly prominent, but it gradually subsides as the strand, on its way to end in the corpus mammillare, becomes more and more sunk in the gray matter on the side of the ventricle.

The third ventricle communicates with both of the lateral ventricles, and also with the fourth ventricle. The **aqueduct of Sylvius**, the narrow channel which tunnels the mesencephalon, brings it into communication with the fourth ventricle. The opening of this aqueduct is placed at the posterior part of the floor of the third ventricle, immediately below the posterior commissure. The **foramina of Monro**

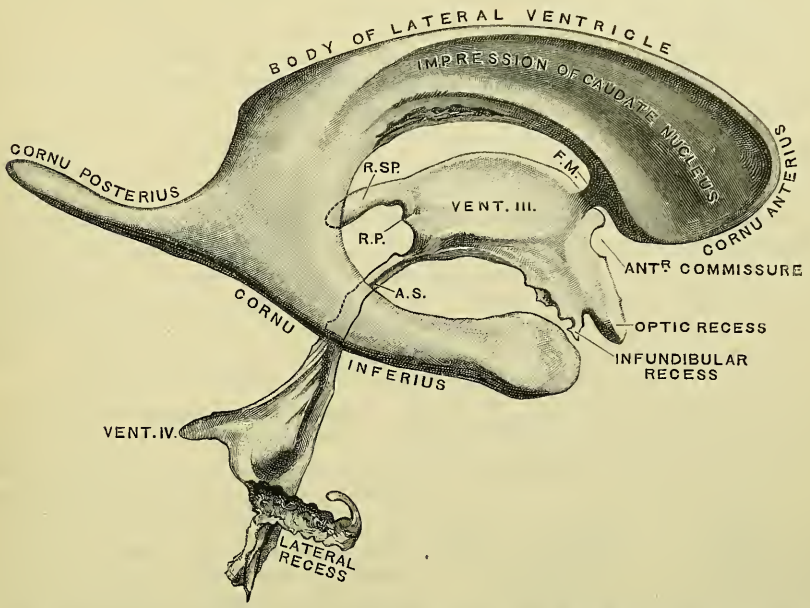


FIG. 444.—PROFILE VIEW OF A CAST OF THE VENTRICLES OF THE BRAIN (from Retzius).

R.SP. Recessus suprapinealis. A.S. Aqueduct of Sylvius.
R.P. Recessus pinealis. F.M. Foramen of Monro.

bring it into communication with the lateral ventricles. These apertures are placed at the upper and fore parts of the lateral walls, and lead outwards and slightly upwards between the most prominent parts of the anterior pillars of the fornix and the anterior tubercles of the optic thalami. They are just large enough to admit a crow-quill, and through these passages the epithelial lining of the three ventricles becomes continuous. From the foramen of Monro a distinct groove on the lateral wall of the ventricle leads backwards towards the mouth of the Sylvian aqueduct. It is termed the **sulcus of Monro**, and is of interest, inasmuch as it is considered by His to represent in the adult brain the furrow which divides the lateral wall of the embryonic brain-tube into an alar and a basal lamina.

The outline of the third ventricle, when viewed from the side in a mesial section through the brain, or as it is exhibited in a plaster cast of the ventricular system of the brain, is seen to be very irregular (Fig 444). It presents several diverticula or recesses. Thus, in the fore-part of the floor there is a funnel-shaped pit or recess, leading down through the tuber cinereum into the infundibulum of the pituitary body. Another recess, the *recessus opticus*, leads forwards immediately in front of this, above the optic chiasma. Posteriorly two diverticula are present. One, the *recessus pinealis*, passes backwards above the posterior commissure and the mouth of the Sylvian aqueduct for a short distance into the stalk of the pineal body. The second is placed above this and is carried backwards for a greater distance. It is a diverticulum of the epithelial roof, and, therefore, is difficult to demonstrate. It is termed the *recessus suprapinealis*.

CEREBRAL CONNEXIONS OF THE OPTIC TRACT.

One nerve, the optic nerve or the nerve of sight, is connected with this section of the brain. At the optic chiasma the optic nerves of the two sides are joined together and a partial decussation of fibres takes place. The fibres which arise in the mesial half of each retina cross the mesial plane and join the optic tract of the

opposite side. The optic tract proceeds backwards round the crus cerebri, and in the neighbourhood of the corpora geniculata divides into two roots, viz. a lateral and a mesial (p. 532).

Mesial Root of the Optic Tract—Commissure of Gudden.—The mesial root of the optic tract disappears under cover of the corpus geniculatum internum and a large proportion of its fibres arise or end in this nuclear body. As to the connexions of the other fibres, we possess at present no precise information. The mesial root, although it is composed of fibres which run in the optic tract, has absolutely nothing to do with the optic nerve. These fibres, when traced forwards, cross the mesial plane in the posterior angle of the optic chiasma and are carried backwards in the opposite optic tract, to form on that side its mesial root. The fibres, therefore, are commissural, and constitute a bond of union, called the **commissure of Gudden**, between the internal geniculate bodies.

Lateral Root of the Optic Tract.—The lateral or true visual root of the optic tract is composed of fibres which come—(1) from the lateral half of the retina of its own side; and (2) from the mesial half of the retina of the opposite side, and which have crossed the mesial plane in the optic chiasma. But in addition to the afferent retinal fibres there are a certain number of efferent fibres in the optic tract, fibres which take their origin in the brain and end in the retina. These are distinguished from the afferent retinal fibres by their exceeding fineness.

The fibres of the lateral root of the optic tract end in the superior quadrigeminal body, in the external geniculate body, and in the pulvinar of the optic thalamus. The fibres to the **superior quadrigeminal body** reach it through the superior brachium (p. 435), and for the most part spread out on its surface in the stratum zonale before they sink into its substance, to end in terminal arborisations around its cells. The **corpus geniculatum externum** receives the largest contribution of fibres from the lateral root of the optic tract. These partly sink into its interior and partly spread out over its surface. The former enter into the construction of the curved lamellæ of white matter which traverse this nuclear mass, and to a large extent end in the gray matter which intervenes between these lamellæ. The deep fibres which are not exhausted in this way proceed onwards through the external geniculate body and enter the pulvinar. Of the superficial fibres which spread over the surface of the external geniculate body some dip into its substance and end there, but the majority are carried over it and enter the stratum zonale of the pulvinar. The fibres of the lateral root of the optic tract, which end in the **pulvinar**, therefore reach their destination by passing either over or through the external geniculate body.

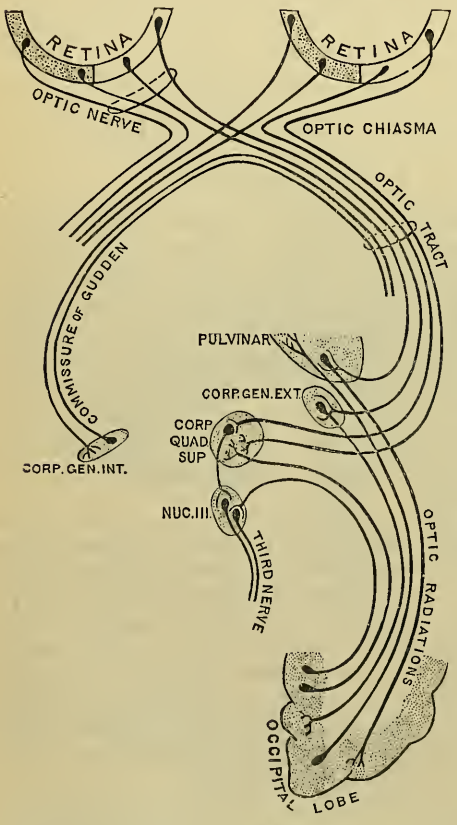


FIG. 445.—DIAGRAM OF THE CENTRAL CONNEXIONS OF THE OPTIC NERVE AND OPTIC TRACT.

Cortical Connexions of the Optic Nerve.—The superior quadrigeminal body, the external geniculate body, and the pulvinar constitute the lower visual centres or terminal nuclei of the visual part of the optic tract. The higher visual centre is placed in the cortex of the occipital lobe of the cerebral hemisphere, and the connexions between this and the lower centres are established by a large strand of fibres which runs in the central white matter of the hinder part of the cerebral hemisphere, and which

constitutes the **optic radiation**. The optic radiation is composed both of corticipetal and corticifugal fibres. The former arise as the axons of the cells in the external geniculate body and the pulvinar, around which the retinal fibres end, and they terminate in the cortex of the occipital lobe. The corticifugal fibres take origin in the cortex of the occipital lobe and end in the pulvinar and superior quadrigeminal body (Ferrier and Turner). Thus constituted, the optic radiation forms a conspicuous strand (Figs. 462, p. 576; 465, p. 579; 473, p. 592), which, reaching the retrolenticular part of the internal capsule, sweeps backwards into the occipital lobe of the cerebral hemisphere on the outer side of the posterior horn of the lateral ventricle. Its connexions will be studied more fully at a later stage.

Flechsig does not believe that the pulvinar is an internode interposed in the path of the optic nerve as it proceeds towards the visual area of the cerebral cortex. He states that he has not been able to convince himself that any fibres of the optic tract end in the optic thalamus.

Other Connexions of the Lower Group of Visual Centres.—(1) The nuclei of the nerves which supply the muscles which move the eyeball would appear to stand in intimate connexion with the lower group of visual centres. Most probably this connexion is established through the posterior longitudinal bundle. As previously stated, Held believes that axons of certain of the cells of the superior quadrigeminal body enter this tract. (2) Through the mesial fillet, the superior quadrigeminal body is connected with the medulla and cord.

THE PARTS DERIVED FROM THE TELENCEPHALON.

Cerebral Hemispheres.

The cerebral hemispheres form the largest part of the fully-developed brain. When viewed from above they form an ovoid mass, the broadest end of which is directed backwards, and the longest transverse diameter of which will be found in the vicinity of the parts which lie subjacent to the parietal eminences of the cranium. The massive rounded character of the anterior or frontal end of each cerebral hemisphere constitutes a leading human characteristic; but the hinder or occipital end is narrow and pointed, and is directed somewhat downwards. The two cerebral hemispheres are separated from each other by a deep mesial cleft, termed the great longitudinal fissure.

Great Longitudinal Fissure (fissura longitudinalis cerebri).—In front and behind the great longitudinal fissure passes from the dorsal to the ventral aspect of the cerebral hemispheres, so as to separate them completely from each other. In its middle part, however, the fissure is interrupted and floored by the corpus callosum, a white commissural band, which passes between the hemispheres and connects them together. The upper surface of the corpus callosum can be displayed by gently drawing asunder the contiguous mesial surfaces of the cerebral hemispheres. The great longitudinal fissure is occupied by a mesial fold of dura mater, termed the falx cerebri, which partially subdivides the part of the cranial cavity allotted to the cerebrum into a right and left chamber.

External Configuration of each Cerebral Hemisphere.—Each cerebral hemisphere presents an external, an internal, and an inferior surface. The *external surface* is convex and is adapted accurately to the deep surface of the cranial vault. The *internal* or *mesial surface* is flat and perpendicular, and bounds the great longitudinal fissure. In great part it is in contact with the falx cerebri; and where that partition is deficient, it is applied to the corresponding portion of the internal surface of the opposite hemisphere. The *inferior surface* is irregular and is adapted to the anterior and middle cranial fossæ of the cranial floor and, behind these, to the upper surface of the tentorium cerebelli. Traversing this surface in a transverse direction, nearer the anterior end of the hemisphere than the posterior end, is the stem of the Sylvian fissure. This deep cleft divides the inferior surface into an anterior or *orbital area*, which rests on the orbital plate of the frontal bone, and is consequently concave from side to side, and a more extensive posterior or *tentorial area*, which lies on the floor of the lateral part of the middle cranial fossa and upon the upper surface of the tentorium cerebelli. This surface is arched from before backwards, and looks inwards as well as downwards. In its hinder two-thirds it lies above the cerebellum, from which it is separated by the tentorium cerebelli.

The borders which intervene between these surfaces are the supero-mesial, the superciliary, the infero-lateral, and the internal occipital. The *supero-mesial border*, convex from before backwards, intervenes between the convex external surface and the flat internal surface of the hemisphere. The *superciliary border* is highly arched and separates the orbital surface from the external surface. The *infero-lateral border* marks off the tentorial surface from the external surface. The *internal occipital border* can only be seen in cases where the brain has been hardened *in situ* and faithfully retains the natural form. It extends from the posterior end of the hemisphere towards the hinder extremity of the corpus callosum, and intervenes between the mesial and tentorial surfaces. It is the border which lies along the straight blood sinus, and it therefore occupies the angle which is formed by the attachment of the posterior part of the falx cerebri to the upper surface of the tentorium cerebelli.

The most projecting part of the anterior end of the cerebral hemisphere is called the **frontal pole**, whilst the most projecting part of the hinder end is termed the **occipital pole.** On the under surface of the hemisphere the prominent point of cerebral substance which extends forwards below the Sylvian fissure receives the name of the **temporal pole.** In a well-hardened brain a broad groove is usually present on the inner and lower aspect of the occipital pole of the right hemisphere. This corresponds to the commencement of the right lateral venous sinus. A less distinct groove on the occipital pole of the left hemisphere frequently indicates the commencement of the left lateral sinus. On the tentorial surface, a short distance behind the temporal pole, a well-marked depression is always visible. This corresponds to the elevation on the anterior surface of the petrous portion of the temporal bone over the superior semicircular canal.

Cerebral Gyri and Sulci.—The surface of the cerebral hemispheres is rendered highly irregular by the presence of convolutions or gyri, separated from each other by intervening furrows of very varying depth, termed sulci or fissures. The surface pattern which is presented by these gyri and sulci is, in its general features, the same in all normal human brains; but when the comparison is pushed into detail many differences become manifest, not only in the brains of different individuals, but also in the two cerebral hemispheres of the same individual.

There are two varieties of furrows, viz. complete and incomplete. The **complete fissures** are few in number, and are formed by inwardly-directed infoldings involving the entire thickness of the cerebral wall. They consequently show in the interior of the cerebral cavity or lateral ventricle in the form of internal elevations on its wall. The complete fissures are the following: (1) the dentate or hippocampal fissure; (2) the anterior part of the calcarine fissure; and (3) a portion of the collateral fissure. The **incomplete fissures** are merely surface furrows of varying depth, which do not produce any effect on the inner surface of the ventricular wall.

General Structure of the Cerebral Hemispheres.—Each cerebral hemisphere is composed of an outside coating of gray matter, spread in a continuous and uninterrupted layer over its surface, and an internal mass of white matter, which forms a considerable part of the immediate wall of the ventricular cavity. The gray coating is termed the **cerebral cortex**, and the internal white matter is called the **medullary centre.** Each convolution shows a corresponding structure. On transverse section it is seen to present an external covering of gray cortex, supported by a central core of white matter.

But, in addition to the gray matter on the outside, there are certain large deposits of gray matter embedded in the basal part of each cerebral hemisphere. These cerebral nuclei constitute the **corpus striatum**, and, although to some extent isolated from the gray matter on the surface, it can be easily shown that at certain points they are directly continuous with it.

By means of the convolutions and sulci, the gray matter on the surface of the hemisphere is enormously increased in quantity without unduly adding to the bulk of the organ; and, further, the vascular pia mater, which dips into every fissure, is increased in extent to a like degree. Opportunity is, therefore, afforded to the cortical vessels of breaking up into twigs of exceeding fineness before they enter the

substance of the hemisphere. The distribution of blood to the gray cortex is, in this way, equalised and rendered uniform.

Cerebral Lobes and Interlobar Fissures.—Certain of the fissures which traverse the surface of the cerebrum are more or less arbitrarily chosen for subdividing the surface into districts or areas, which are termed lobes. These fissures are termed **interlobar**, and are the following: (1) the fissure of Sylvius; (2) the fissure of Rolando; (3) the parieto-occipital; (4) the calloso-marginal; (5) the collateral; and (6) the limiting sulcus of Reil.

The lobes which are mapped out by these fissures are: (1) the frontal; (2) the parietal; (3) the occipital; (4) the temporal; (5) the insula, or the island of Reil; (6) the limbic. To these may be added a seventh lobe, in no way related to the interlobar fissures, viz. the olfactory lobe. With the exception of the occipital and olfactory lobes and the insula, this subdivision of the hemisphere possesses little morphological value, and is chiefly adopted for topographical purposes.

Fissure of Sylvius (fissura cerebri lateralis).—This is the most conspicuous

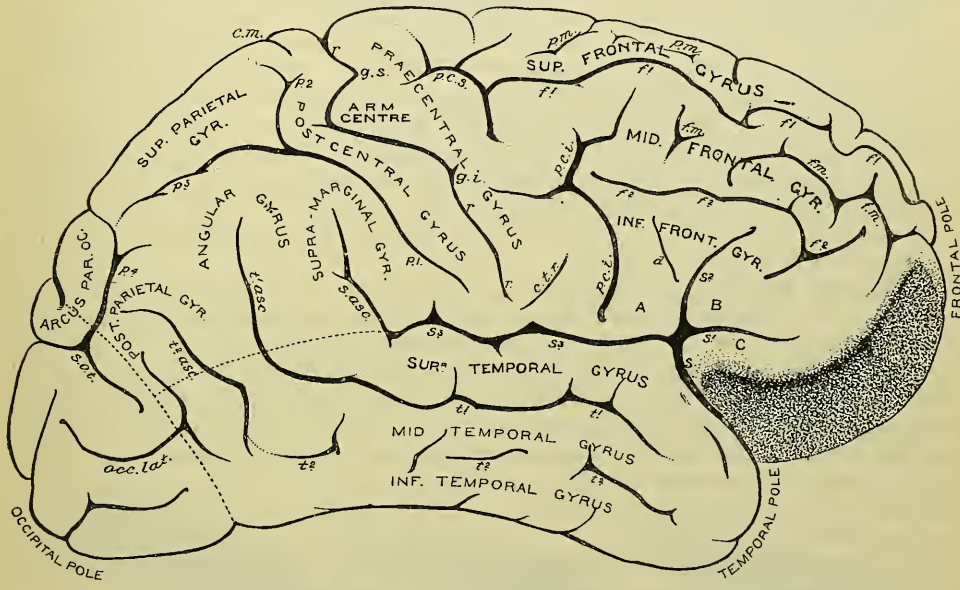


FIG. 446.—GYRI AND SULCI, on the outer surface of the cerebral hemisphere.

f^1.	Sulcus frontalis superior.
f^2.	Sulcus frontalis inferior.
f.m.	Sulcus frontalis medius.
p.m.	Sulcus paramedialis.
A.	Pars basilaris.
B.	Pars triangularis.
C.	Pars orbitalis.
S.	Sylvian fissure.
s^1.	Anterior horizontal limb (Sylvian fissure).
s^2.	Ascending limb (Sylvian fissure).
s^3.	Posterior horizontal limb (Sylvian fissure).
s.asc.	Ascending terminal part of the posterior horizontal limb of the Sylvian fissure.
p.c.i.	Inferior præcentral sulcus.
p.c.s.	Superior præcentral sulcus.
r.	Fissure of Rolando.
g.s.	Superior genu.
g.i.	Inferior genu.
d.	Sulcus diagonalis.
t^1.	Superior temporal sulcus (parallel sulcus).
t^2.	Inferior temporal sulcus.
p^1.	Inferior postcentral sulcus.
p^2.	Superior postcentral sulcus.
p^3.	Ramus horizontalis.
p^4.	Ramus occipitalis.
s.o.t.	Sulcus occipitalis transversus.
occ. lat.	Sulcus occipitalis lateralis (the sulcus lunatus of Elliot Smith).
c.m.	Calloso-marginal sulcus.
c.t.r.	Inferior transverse furrow.

fissure on the surface of the cerebral hemisphere. It is composed of a short main stem, from the outer extremity of which three branches or limbs radiate. The **stem** of the Sylvian fissure is placed on the inferior surface of the hemisphere. It begins at the locus perforatus anticus in a depression termed the **vallecula Sylvii**. From this it passes horizontally outwards, forming a deep cleft between the temporal pole and the orbital surface of the frontal lobe. Appearing on the outer surface of the hemisphere at a point called the **Sylvian point**, the Sylvian fissure immediately divides into three radiating branches. These are: (1) the

ramus horizontalis posterior; (2) the ramus horizontalis anterior; (3) the ramus anterior ascendens.

The **posterior horizontal limb** is the longest and best marked of the three limbs. It extends backwards, with a slight inclination upwards on the outer surface of the hemisphere for a distance which may vary from about two to three inches. It intervenes between the frontal and parietal lobes which lie above it and the temporal lobe which lies below it, and it finally ends in the region subjacent to the parietal eminence of the cranial wall by turning upwards into the parietal lobe in the form of an *ascending terminal piece.*

The **anterior horizontal limb** extends horizontally forwards in the frontal lobe for a distance of about three-quarters of an inch immediately above and parallel to the posterior part of the superciliary margin of the hemisphere.

The **ascending limb** proceeds upwards, with a slight inclination forwards, into the lower part of the outer surface of the frontal lobe for a distance of about an inch. In many cases the two anterior limbs spring from a common stem of greater or less length, and not infrequently both are replaced by a single anterior limb.

Limiting Sulcus of Reil (sulcus circularis Reilii).—If the lips of the posterior horizontal limb of the Sylvian fissure be widely pulled asunder from each other, the insula or island of Reil will be seen at the bottom. The insular district of the cortex is completely hidden from view when the Sylvian fissure is closed by overlapping portions of the cerebral hemisphere, and, when brought into view in the manner indicated, it is observed to present a triangular outline and to be surrounded by a limiting sulcus, of which three parts may be recognised, viz.: an *upper part,* bounding it above and separating it from the parietal and frontal lobes; a *lower part,* marking it off below from the temporal lobe; and an *anterior part,* separating it in front from the frontal lobe.

Opercula Insulæ.—The overlapping portions of the cerebral substance which cover over the insula are termed the insular opercula, and they form, by the apposition of their margins, the three limbs of the Sylvian fissure. The opercula are four in number and are named: (1) temporal; (2) fronto-parietal; (3) frontal; and (4) orbital. The limbs of the Sylvian fissure cut right through between the different opercula and extend from the exposed surface of the hemisphere to the submerged surface of the insula, and, in this manner, separate the opercula from each other.

The **temporal operculum** extends upwards over the insula from the temporal lobe, and its upper margin forms the lower lip of the posterior horizontal limb of the Sylvian fissure.

The **fronto-parietal operculum** is carried downwards from the parietal and frontal regions over the insula, and its lower margin, meeting the temporal operculum, forms the upper lip of the posterior limb of the Sylvian fissure.

The **frontal operculum** is the small triangular piece of cerebral substance which intervenes between the ascending and anterior horizontal limbs of the Sylvian fissure. It covers over a small part of the anterior portion of the insula, and is sometimes termed the **pars triangularis.**

The **orbital operculum** is, for the most part, on the under surface of the hemisphere. It lies below and to the inner side of the anterior horizontal limb of the Sylvian fissure, and proceeds backwards from the orbital aspect of the frontal lobe over the fore-part of the insula.

Development of the Sylvian Fissure and of the Insular District of the Cerebral Hemisphere.—It is only during the latter half of the intrauterine period of development that the opercula take shape and grow over the insula, so as to shut it out from the surface. In its early condition the insula presents the form of a depressed area on the side of the cerebral hemisphere, surrounded by a distinct boundary wall formed by the surrounding more elevated surface of the hemisphere (Fig. 447, A). After a time this depressed area, which is called the Sylvian fossa, assumes a triangular outline, and then the bounding wall is observed to be composed of three distinct parts, viz.: an upper or fronto-parietal, a lower or temporal, and an anterior or orbital part (Fig. 447, B). The rounded angle, formed by the meeting of the upper and anterior portions of the boundary, now becomes flattened, and a short oblique part of the limiting wall, termed the frontal portion, assumes shape in this position. Each of these four portions of the bounding wall of the Sylvian fossa becomes a line of growth, from which an operculum takes origin, and by the approximation of these opercula, as they grow over the surface of the Sylvian fossa, the insula becomes closed in and the limbs of the Sylvian fissure are formed (Fig. 448).

The temporal and fronto-parietal opercula make their appearance somewhere about the end of the fifth month of fœtal development, long before the other two opercula show any indication of growth. The temporal operculum grows more rapidly than the fronto-parietal ; so that, when the margins of these two opercula come together to form the posterior limb of the Sylvian fissure, there is a greater extent of the Sylvian fossa covered by the temporal operculum than by the fronto-parietal operculum. This accounts for the more oblique direction of the Sylvian fissure in the fœtal brain. But at this stage a growth-antagonism between the two opercula takes place, and in this the fronto-parietal operculum proves the victor. The contiguous lips of the two opercula become, in the first instance, tightly pressed together, and then, as the upper operculum proves the stronger and the more vigorous in its growth, the posterior limb of the Sylvian fissure becomes gradually depressed until it assumes the inclination characteristic of the adult. It would appear that the opercular growth-antagonism which produces this effect in the human brain does not occur to the same extent, if indeed it occurs at all, in the ape. This is evident from the oblique direction of the posterior limb of the Sylvian fissure in the simian brain. The greater growth-energy of the fronto-parietal operculum in the human brain is not confined to the fœtal stage of development, but is carried into the earlier stages of infantile growth, and it is probable that it is due to an extension of that district of the cortex in which the centres for the skilled movements of the upper limbs reside, and also to an extension of Flechsig's parieto-occipital association area.

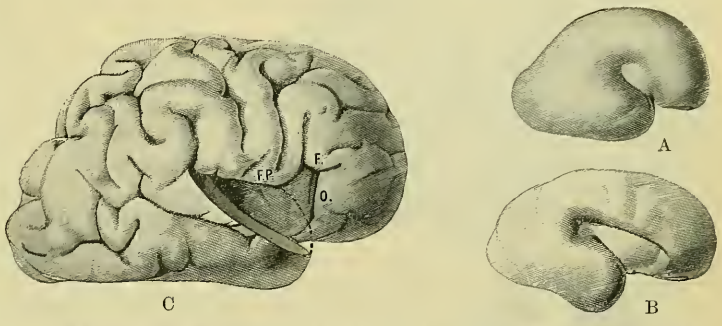


Fig. 447.—Three Stages in the Development of the Insula and the Insular Opercula.

A, Right cerebral hemisphere from a fœtus in the latter part of the fourth month of development ; B, Right cerebral hemisphere from a fœtus in the fifth month of development ; C, Right cerebral hemisphere from a fœtus in the latter part of the eighth month of development.

In C the temporal operculum has been removed, and thus a large part of the insula is exposed. The outline of the temporal operculum is indicated by a dotted line.

F.P. Fronto-parietal operculum. F, Frontal operculum. O, Orbital operculum.

The orbital and frontal opercula are late in appearing and very tardy in their growth. Indeed, it is only during the course of the first year of infantile life that they come into apposition

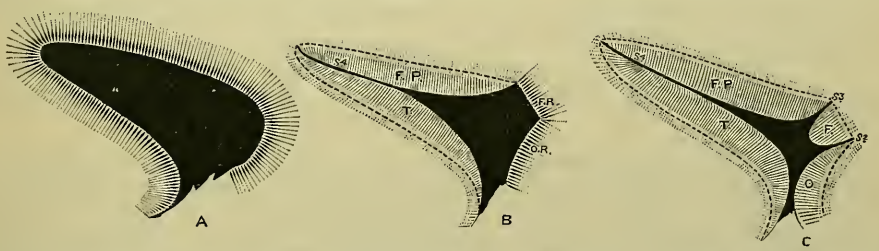


Fig. 448.—Diagram to Illustrate the Development of the Opercula which cover the Insula.

A, Sylvian fossa before opercula begin to form ; B, Fronto-parietal and temporal opercula well advanced ; C, All the four opercula developed but not in apposition.

F.P. Fronto-parietal operculum. O.R. Orbital wall of fossa. s^2. Anterior horizontal limb of Sylvian fissure.
T. Temporal operculum. F. Frontal operculum. s^3. Ascending limb.
F.R. Frontal wall of fossa. O. Orbital operculum. s^4. Posterior horizontal limb.

with each other and with the other two opercula, so as to close in the fore-part of the Sylvian fossa and form the anterior limbs of the Sylvian fissure. They do not begin to take shape until more than half of the Sylvian fossa has already been closed by the fronto-parietal and the temporal opercula. The orbital operculum appears first and is much more constant in its growth than the frontal operculum, which indeed frequently fails altogether, and, even when present, shows the greatest amount of variability in the degree to which it is developed.

Variations in the degree of development of the frontal operculum influence greatly the form presented by the two anterior limbs of the Sylvian fissure, between which it lies. When strongly developed, it separates the two Sylvian limbs from each other to such an extent that they assume the appearance of the letter U ; when the frontal operculum is less strongly marked, the anterior Sylvian limbs may assume a V form or a Y form. In the latter case, the orbital and the fronto-parietal opercula meet below the frontal operculum to form the stem of the Y. In those cases

where the frontal operculum is absent altogether, a single anterior limb of the Sylvian fissure is the result.

The late appearance, the slow growth, the variability of these two opercula, and also the tendency to abortive growth or complete suppression of the frontal operculum, all bespeak the fact that, from a phylogenetic point of view, the frontal and orbital opercula are, comparatively speaking, recent productions in the evolution of the human brain. In the anthropoid ape they are absent, and, consequently, the fore-part of the island of Reil is exposed on the surface of the simian brain. The same condition is not at all an uncommon occurrence in the brain of the microcephalic idiot.

Fissure of Rolando (sulcus centralis).—The fissure of Rolando takes an oblique course across the outer convex surface of the cerebral hemisphere, and intervening between the frontal and parietal lobes it forms the immediate posterior boundary of the motor area of the cortex. Its upper end cuts the supero-mesial border of the hemisphere a short distance behind the mid-point between the frontal and occipital poles, whilst its lower end terminates above the middle of the posterior horizontal limb of the fissure of Sylvius. Its superior extremity, as a rule, turns round the supero-mesial border of the hemisphere, and is then continued backwards for a short distance on the mesial surface. Although, in its general direction, the fissure is oblique, it is very far from being straight. It takes a sinuous course across the hemisphere. This is largely due to the area of cortex which represents the motor centre for the arm, and which lies in front of the sulcus, growing backwards in the course of its development so as to produce a bay in the fissure within which this portion of the cortex is accommodated. The bends in the fissure which indicate the upper and lower limits of the arm centre (Grünbaum and Sherrington) are termed respectively the *superior* and *inferior genua*. The angle which the general direction of the fissure of Rolando makes with the mesial plane is termed the **Rolandic angle**. In the adult brain the average Rolandic angle is 71° 7′, and the limits of variation would appear to be 69° and 74°.

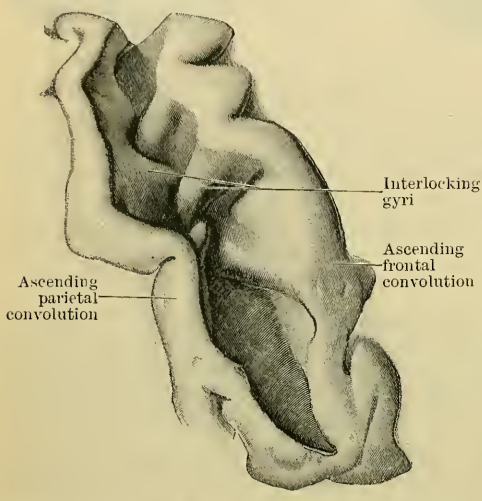


Fig. 449.—Fissure of Rolando fully opened up, so as to exhibit the interlocking gyri and deep annectant gyrus within it.

When the fissure of Rolando is widely opened up, so that its bottom and its opposed sides may be fully inspected, it will be seen that, between the two genua, the two bounding convolutions are dovetailed into each other by a number of interlocking gyri, which do not appear on the surface (Fig. 449). Further, two of these, placed on opposite sides of the fissure, are frequently joined across the bottom of the sulcus in the form of a sunken bridge of connexion, which constitutes what is termed a *deep annectant gyrus*. The continuity of the fissure is thus, to some extent, interrupted. This condition is rendered interesting when considered in connexion with the development of the sulcus. The deep interlocking gyri indicate a great exuberance of cortical growth in this situation in the early stages of the development of the fissure; and the presence of the deep annectant gyrus is explained by the fact that the fissure of Rolando generally develops in two pieces, which run into each other to form the continuous sulcus of the adult, viz. a part corresponding to the lower two-thirds, and an upper part, which represents the upper third and which appears at a slightly later date. In certain very rare cases the fissure of Rolando is found to remain double throughout life, through a failure of its two pieces to unite. In such cases the deep annectant gyrus, which is frequently seen at the bottom of the furrow, remains on the surface. Heschl, who examined 2174 cerebral hemispheres, only found this anomaly six times; Eberstaller met with it twice in 200 brains.

Parieto-occipital Fissure.—A small part of this fissure appears on the outer face of the cerebral hemisphere. For the most part it is situated on the internal surface. It is customary, therefore, to describe an external parieto-occipital and an internal parieto-occipital fissure. It must be clearly understood, however, that they are directly continuous with each other round the supero-mesial border of the

hemisphere. The parieto-occipital fissure intervenes between the parietal and occipital lobes.

The **external parieto-occipital fissure** cuts the supero-mesial border of the hemisphere in a transverse direction at a distance of from one and a half to two inches in front of the occipital pole. It is, as a rule, not more than about a half an inch long, and it is brought to an abrupt termination by an arching convolution, which winds round its extremity and receives the name of **arcus parieto-occipitalis.**

The **internal parieto-occipital fissure** is carried downwards on the inner surface of the hemisphere in a nearly vertical direction as a conspicuous and deep cleft. A short distance behind the hinder end of the corpus callosum its lower extremity runs into the calcarine fissure.

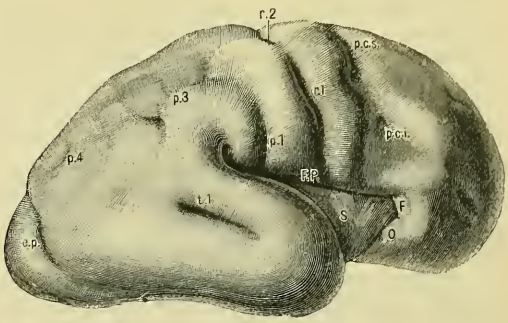


FIG. 450.—LEFT CEREBRAL HEMISPHERE, from a fœtus in the early part of the seventh month of development.

p.c.s.	Sulcus præcentralis superior.	
p.c.i.	Sulcus præcentralis inferior.	
r^1.	Lower part of Rolandic fissure.	
r^2.	Upper part of Rolandic fissure.	
p^1.	Inferior postcentral sulcus	Intraparietal fissure.
p^2.	Ramus horizontalis	
p^4.	Ramus occipitalis	
e.p.	External perpendicular fissure of Bischoff.	
t^1.	Parallel sulcus.	
S.	Sylvian fossa.	
F.P.	Fronto-parietal wall.	
F.	Frontal wall.	
O.	Orbital wall.	

The parieto-occipital fissure is developed, as a rule, after the manner of a complete fissure. In the fœtal brain it forms a very evident infolding of the cerebral wall. In the adult brain, however, it does not form any eminence on the inner wall of the ventricle, because it does not extend downwards as far as the cavity. The wall of the ventricle during the growth of the hemisphere has thickened to such an extent that the part corresponding to the fissure has become solid.

Collateral Fissure (fissura collateralis).—The collateral sulcus is a strongly-marked fissure on the tentorial face of the cerebral hemisphere. It begins near the occipital pole and extends forwards towards the temporal pole. In its posterior part it is placed below, and parallel to, the calcarine fissure, whilst in front it is

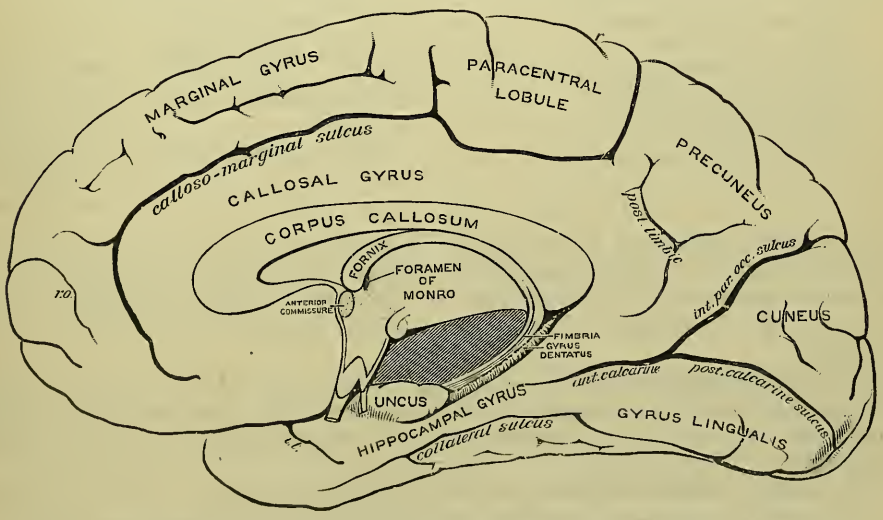


FIG. 451.—THE GYRI AND SULCI ON THE MESIAL ASPECT OF THE CEREBRAL HEMISPHERE.
r. Fissure of Rolando. *r.o.* Rostral sulcus. *t.t.* Incisura temporalis.

separated from the hippocampal or dentate fissure by the hippocampal gyrus, which is the innermost convolution on the tentorial surface of the hemisphere.

In front of the anterior extremity of the collateral fissure a shallow sulcus turns round the anterior end of the temporal lobe, so as to intervene between the temporal

pole and the uncinate or hook-like extremity of the hippocampal convolution. This is the **incisura temporalis**, or **ecto-rhinal fissure**. The collateral fissure and the incisura temporalis intervene between the limbic and temporal lobes.

The collateral fissure is developed, as a rule, in three portions—a hinder or occipital, an intermediate, and an anterior or temporal part. These ultimately run into each other and form the continuous fissure. The middle part is usually a complete fissure and responsible for the production of the *eminentia collateralis posterior* in the floor of the trigonum of the lateral ventricle; the temporal part is sometimes a complete fissure, forming when it is so the *eminentia collateralis anterior*; the occipital part is always incomplete.

Calloso-marginal Fissure.—This fissure is a strongly-marked sulcus on the fore-part of the mesial surface of the hemisphere. It divides the front portion of the mesial surface into an upper marginal and a lower callosal convolution, and intervenes between the frontal and limbic lobes. Beginning below the fore-end of the corpus callosum, close to the locus perforatus anticus, the calloso-marginal fissure curves round in front of the genu of the corpus callosum, and then extends backwards to a point a short distance behind the middle of the mesial surface. It then turns upwards and cuts the supero-mesial border of the hemisphere, immediately behind the upper end of the fissure of Rolando. The relation presented by the two extremities of these fissures is such that they can both be readily recognised either when examined on the outer or mesial aspect of the cerebrum.

The calloso-marginal sulcus is developed in two or three separate pieces, which, as growth proceeds, run into each other and form the continuous fissure. The numerous cases of irregular arrangement met with in connexion with this fissure can generally be explained by this interrupted mode of development.

Frontal Lobe.—The frontal lobe is the largest of the cerebral lobes. On the outer surface of the hemisphere, it is bounded behind by the fissure of Rolando and below by the posterior horizontal limb of the fissure of Sylvius. On the mesial face it is limited by the calloso-marginal fissure, whilst on the inferior surface of the hemisphere the stem of the Sylvian fissure forms its posterior boundary. It presents an outer surface, a mesial surface, and an inferior or orbital surface.

On the *outer surface of the frontal lobe* the following sulci and gyri may be recognised:—

- Sulci
  - Sulcus præcentralis inferior.
  - Sulcus præcentralis superior.
  - Sulcus paramedialis.
  - Sulcus frontalis superior.
  - Sulcus frontalis medius.
  - Sulcus frontalis inferior.
  - Sulcus diagonalis.
  - Sulcus fronto-marginalis.
- Gyri
  - Gyrus frontalis ascendens or gyrus centralis anterior.
  - Gyrus frontalis superior
    - pars superior.
    - pars inferior.
  - Gyrus frontalis medius
    - pars superior.
    - pars inferior.
  - Gyrus frontalis inferior
    - pars basilaris.
    - pars triangularis.
    - pars orbitalis.

The **inferior præcentral sulcus** consists of a vertical and a horizontal part, and when developed in a typical manner, it presents a figure like the letter T or F. The *vertical portion* lies in front of the lower part of the fissure of Rolando, whilst the *horizontal part* extends obliquely forwards and upwards into the middle frontal convolution.

The **superior præcentral sulcus** is a short vertical sulcus which lies at a higher level than the inferior præcentral furrow, in front of the upper part of the fissure of Rolando. It is almost invariably connected with the hinder end of the superior frontal sulcus.

The **anterior central convolution** (ascending frontal gyrus) is a long continuous gyrus, which is limited in front by the two præcentral furrows and behind by the fissure of Rolando. It extends obliquely across the hemisphere from the supero-mesial margin above to the posterior horizontal limb of the Sylvian fissure below.

The **superior frontal sulcus** extends forwards in a more or less horizontal direction from the sulcus præcentralis superior.

The **gyrus frontalis superior** is the narrow convolution between the supero-mesial

border of the hemisphere and the superior frontal sulcus. It takes a horizontal course to the frontal pole.

The **inferior frontal sulcus** occupies a lower level than the superior frontal furrow. Its hinder end is placed in the angle between the vertical and horizontal parts of the inferior præcentral sulcus, and is not infrequently confluent with one or other of these. It proceeds forwards towards the superciliary margin of the hemisphere and ends a short distance from this in a terminal bifurcation.

The **gyrus frontalis medius** is the name given to the broad convolution which lies between the superior and inferior frontal sulci.

The **gyrus frontalis inferior** is that portion of the outer surface of the frontal lobe which is placed in front of the inferior præcentral sulcus and below the inferior frontal sulcus. The inferior frontal convolution is cut into three pieces by two anterior limbs of the Sylvian fissure. These are termed the pars basilaris, the pars triangularis, and the pars orbitalis.

The **pars basilaris** is that part which lies between the vertical limb of the inferior præcentral sulcus and the ascending limb of the Sylvian fissure. It forms the anterior part of the fronto-parietal operculum, and it is traversed in an oblique direction by a shallow but constant furrow, termed the **sulcus diagonalis.** The **pars triangularis** is simply another name for the frontal operculum. It is triangular in form, and lies between the anterior ascending and the anterior horizontal limbs of the Sylvian fissure. The **pars orbitalis** is placed below the anterior horizontal limb of the Sylvian fissure.

The inferior frontal convolution possesses a special interest on account of the localisation within it, on the left side, of the speech centre. From it, also, the front part of the fronto-parietal and the whole of the frontal operculum are developed. This opercular development in connexion with the inferior frontal gyrus constitutes a leading point of difference between the brain of man and that of the ape. Even in the highest ape the inferior frontal convolution is not opercular. The frontal operculum is not present and the anterior part of the insula is exposed on the surface. Probably the excess of growth which determines the formation of the frontal operculum in man has some connexion with the development of the speech centre.

The **sulcus paramedialis** is the term applied to a series of short irregular depressions or furrows, arranged longitudinally, close to the supero-mesial border of the hemisphere. These rudimentary sulci partially subdivide the superior frontal convolution into an upper and a lower part, and they are of interest in so far that they are not as a rule developed in the higher apes, and are deeper and better marked in the higher than the lower types of human brain.

The **sulcus frontalis medius** (Eberstaller) proceeds horizontally forwards in the forepart of the middle frontal convolution, so as to subdivide it into an upper and a lower part. When the furrow reaches the superciliary margin of the hemisphere it bifurcates, and its terminal branches spread out widely and constitute a transverse furrow, called the *fronto-marginal sulcus.* The sulcus frontalis medius is only found in man and the anthropoid apes. It is not present in any of the lower apes.

Owing to the subdivision of the superior and middle frontal convolutions in the manner indicated, the typical arrangement of the convolutions in the anterior part of the outer surface of the frontal lobe is in five horizontal tiers, and not in three tiers, as formerly described.

As a rule, the sulci on the outer surface of the frontal lobe during the process of development appear in the following order: (1) sulcus præcentralis inferior; (2) sulcus frontalis inferior; (3) sulcus præcentralis superior and sulcus frontalis superior; (4) sulcus frontalis medius; (5) sulcus paramedialis. This gives some indication of the relative morphological importance of these sulci, although it should be borne in mind that the period at which sulci appear on the fœtal brain cannot in every case be taken as affording an infallible guide in our attempts to assign to them their relative morphological value.

On the *mesial aspect of the frontal lobe* there is an elongated more or less continuous convolution, called the **gyrus marginalis.** It lies between the supero-mesial margin of the hemisphere and the calloso-marginal fissure. In the fore-part of this gyrus one or two curved sulci are usually present. They are termed the **sulci rostrales.** The posterior part of the marginal convolution is more or less completely cut off from the portion which lies in front. This part is called the

paracentral lobule, and into it the upper end of the fissure of Rolando is prolonged as it turns over the supero-mesial border of the hemisphere.

On the *orbital aspect of the frontal lobe* there are two sulci, viz. the olfactory and the orbital.

The **olfactory sulcus** is a straight furrow which runs parallel to the mesial border of the hemisphere. It is occupied by the olfactory tract and bulb, and it cuts off a narrow strip of the orbital surface close to the mesial border, which receives the name of **gyrus rectus.**

The **orbital sulcus** is a composite furrow which assumes many different forms. As a general rule it presents a shape similar to that of the letter H, and is then composed of three parts, viz. an external limb, an internal limb, and a transverse limb. The **external limb** (sulcus orbitalis externus) curves round the orbital part of the inferior frontal convolution, so as to limit it on this aspect of the brain. The **internal limb** (sulcus orbitalis internus) is frequently broken up into two pieces. It marks off a convolution between itself and the olfactory sulcus, called the **gyrus orbitalis internus.** The **transverse limb** (sulcus orbitalis transversus) takes a curved course between the internal and external limbs. The district in front is termed the **gyrus orbitalis anterior**, and that behind the **gyrus orbitalis posterior.** The latter, in its outer part, corresponds with the orbital operculum.

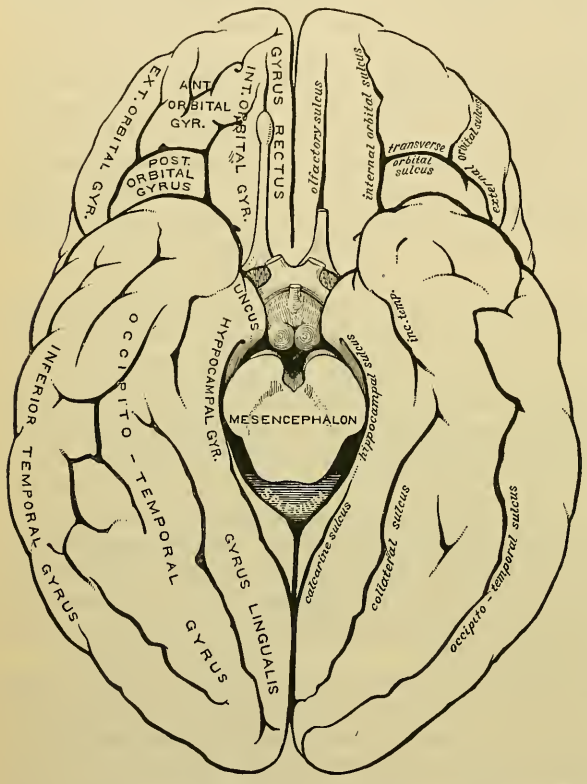


FIG. 452.—GYRI AND SULCI on the tentorial and orbital aspects of the cerebral hemispheres.

PARIETAL LOBE. — The parietal lobe forms a considerable part of the external surface of the cerebral hemisphere, and it also appears on the inner surface in the form of the præcuneus or the quadrate lobule. *In front*, it is bounded by the fissure of Rolando, which separates it from the frontal lobe. *Below*, it is limited in its fore-part by the posterior horizontal limb of the fissure of Sylvius. Behind the upturned end of this fissure the surface of the parietal lobe is continuous inferiorly with that of the temporal lobe, and an arbitrary line drawn backwards on the surface of the brain, in continuation of the horizontal part of the posterior limb of the Sylvian fissure, is taken as its inferior limit. *Posteriorly*, it is separated from the occipital lobe at the supero-mesial border of the hemisphere by the external parieto-occipital fissure. Below this fissure the surface of the parietal lobe is continuous with that of the occipital lobe; and an arbitrary line drawn across the outer surface of the hemisphere, from the extremity of the external parieto-occipital fissure to an indentation on the infero-lateral border of the hemisphere, termed the **præoccipital notch**, may be regarded as furnishing a posterior limitation.

The præoccipital notch is, as a rule, only visible in brains that have been hardened *in situ*. It is placed on the infero-lateral border of the hemisphere, about an inch and a half in front of the occipital pole, and is produced by a vertical fold or wrinkle of the dura mater on the deep aspect of the parieto-mastoid suture, and immediately above the highest part of the lateral blood-sinus.

There is great variability in the degree to which this fold of dura mater projects in different

individuals. In the child it is always very salient, and often produces a deep cleft in the brain, but as the full size of the cranium is gradually attained it becomes much less projecting. In the young skull two or three such folds in this locality are frequently apparent. Related to the præoccipital notch there are likewise some cerebral veins which turn round the infero-lateral margin of the hemisphere to join the lateral blood-sinus.

On the *mesial surface of the hemisphere* the parietal lobe is represented by the **præcuneus** or **quadrate lobule**. This district, which is somewhat quadrilateral in form, lies between the upturned end of the calloso-marginal sulcus and the internal parieto-occipital fissure. It is imperfectly separated below from the limbic lobe by a somewhat variable furrow called the **post-limbic sulcus**.

The gyri and sulci, on the *outer surface of the parietal lobe*, are the following :—

- Sulci
  - Sulcus intraparietalis (of Turner).
    - Sulcus postcentralis inferior.
    - Sulcus postcentralis superior.
    - Ramus horizontalis.
    - Ramus occipitalis.
  - Upturned ends of—
    - (*a*) Sylvian fissure.
    - (*b*) Parallel fissure.
    - (*c*) Second temporal fissure.
- Gyri
  - Gyrus ascendens parietalis or gyrus postcentralis.
  - Gyrus parietalis superior.
  - Gyrus parietalis inferior
    - Gyrus supramarginalis.
    - Gyrus angularis.
    - Gyrus postparietalis.

The **intraparietal sulcus** (of Turner) is a composite furrow, and is built up of four originally distinct factors. Two of these, termed the sulcus postcentralis inferior and the sulcus postcentralis superior, take a more or less oblique course across the hemisphere, and are most frequently united into one continuous fissure. The other two factors are placed horizontally, one behind the other, and are termed the ramus horizontalis and the ramus occipitalis.

The **sulcus postcentralis inferior** lies behind the lower part of the fissure of Rolando, whilst the **sulcus postcentralis superior** occupies a similar position in relation to the upper part of that fissure. When confluent they form a long, continuous fissure, which stretches across the hemisphere behind the fissure of Rolando and parallel to it.

The **ramus horizontalis** is continuous, as a rule, with the upper end of the sulcus postcentralis inferior, and extends backwards, with a slight inclination upwards between the superior parietal gyrus, which lies above it, and the inferior parietal gyrus, which is placed below it. With the two confluent postcentral sulci it presents a figure like the letter ⊣ placed on its side.

The **ramus occipitalis** is a curved sulcus which bounds externally the arcus parieto-occipitalis, or, in other words, the arching convolution which surrounds the external parieto-occipital fissure. The ramus occipitalis lies behind the ramus horizontalis, and is generally linked on to it; less frequently it is separate. The posterior end of the ramus occipitalis enters the occipital lobe, and, behind the arcus parieto-occipitalis, bifurcates into two widely spread-out branches. These form a short transverse fissure in the occipital lobe, termed the **sulcus occipitalis transversus**

In the human brain the intraparietal sulcus is usually developed in four separate pieces, corresponding to the four portions of the fissure which have been described as being present in the adult brain. The sulcus postcentralis inferior appears first (somewhere about the end of the sixth month), then the ramus occipitalis and the ramus horizontalis; last of all the sulcus postcentralis superior comes into view. The further development of the sulcus consists in the running together of these early pieces. This takes place in different ways, and not infrequently union fails at one or more points, and thus a great variety of combinations may be noted in different individuals; indeed, it may be said that every possible kind of combination may be met with. The most common form which the fissure assumes, however, is that in which all its factors have become confluent and one continuous furrow results. When such an intraparietal furrow is widely opened up, certain deep annectant gyri, which cross the bottom of the sulcus, come into view. These interrupt the sulcus at the points of union between its several pieces and indicate its original multiple formation.

There is reason to believe that three of the elements of the human intraparietal sulcus, viz. the sulcus postcentralis inferior, the ramus horizontalis, and the ramus occipitalis, are disrupted portions of the primitive single continuous fissure which is seen in certain of the lower apes (Cebus), whilst one, the sulcus postcentralis superior, is a superadded element.

There is a strong analogy between the postcentral sulcus, the fissure of Rolando, and the

præcentral sulcus. They form a group of radial sulci on the outer surface of the fœtal cerebrum above the Sylvian region. The fissure of Rolando makes its appearance first, then the præcentral sulcus, and, lastly, the postcentral sulcus. Each assumes shape in the first instance in two pieces, viz. an upper and lower. The two pieces of the fissure of Rolando join early, and only in very rare instances remain separate; the two pieces of the postcentral furrow usually join, but in 19 per cent of cerebral hemispheres they remain separate; the two pieces of the præcentral furrow, as a rule, remain separate and distinct.

The **sulcus transversus occipitalis**, or bifurcated extremity of the ramus occipitalis, has been

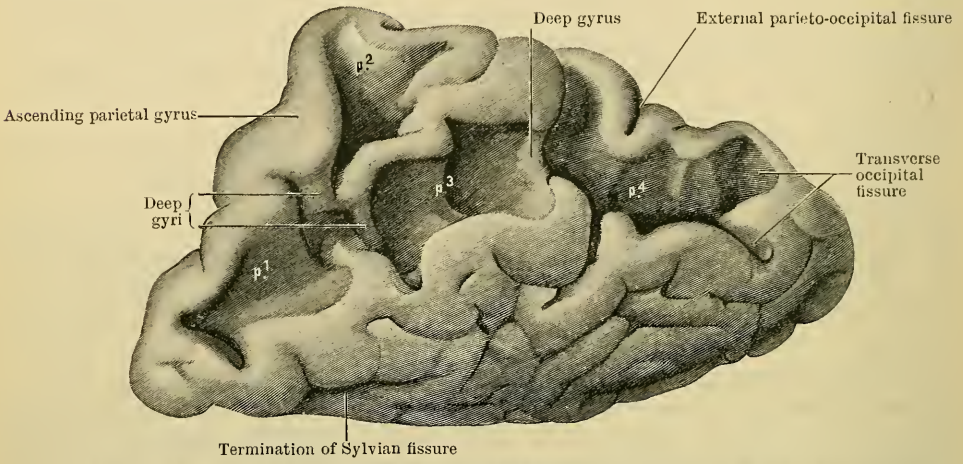


FIG. 453.—THE INTRAPARIETAL SULCUS FULLY OPENED UP, so as to show its several parts and the deep annectant gyri intervening between them.

p^1. Sulcus postcentralis inferior.
p^2. Sulcus postcentralis superior.
p^3. Ramus horizontalis.
p^4. Ramus occipitalis.

until lately generally believed to be the representative in the human brain of the conspicuous "Affenspalte," in the cerebrum of the ape. The accuracy of this view was challenged in 1892 (*Cunningham Memoir*, No. vii. Roy. Irish Acad.), and recently Elliot Smith has brought forward evidence of a very convincing kind which seems to show that in the human brain the "Affenspalte" is represented by the sulcus occipitalis lateralis of Eberstaller.

The intraparietal sulcus maps out three districts or gyri on the external surface of the parietal lobe, viz. the posterior central convolution, the superior parietal gyrus, and the inferior parietal gyrus.

The upturned ends of the fissure of Sylvius, of the first temporal or parallel sulcus, and of the second temporal sulcus ascend for a short distance, one behind the other, into the inferior parietal gyrus.

The **posterior central convolution** (ascending parietal convolution) is a long gyrus which extends obliquely across the hemisphere from the supero-mesial border above to the Sylvian fissure below. It is bounded in front by the fissure of Rolando and behind by the superior and inferior postcentral sulci.

The **superior parietal gyrus** is the area of cerebral cortex which lies between the supero-mesial border of the hemisphere above and the ramus horizontalis below. In front it is bounded by the superior postcentral sulcus, whilst behind it is connected with the occipital lobe by the arcus parieto-occipitalis. It is continuous round the supero-mesial border with the præcuneus.

The **inferior parietal gyrus** lies below the ramus horizontalis and the ramus occipitalis and behind the inferior præcentral sulcus. It is more or less directly continuous with the occipital lobe behind and the temporal lobe below. From before backwards it presents three arching convolutions, viz. the supra-marginal, the angular, and the postparietal. The **supramarginal convolution** is bent round the upturned end of the posterior limb of the Sylvian fissure, and stands in continuity behind and below this, with the first temporal gyrus. The **angular convolution** arches over the upturned end of the parallel sulcus and becomes continuous with the second temporal convolution. The **postparietal convolution** winds round the upturned end of the second temporal sulcus and runs into the third temporal gyrus.

OCCIPITAL LOBE.—The occipital lobe forms the hinder pyramidal part of the

cerebral hemisphere; and although very imperfectly mapped off from the temporal and parietal lobes, which lie in front of it, it is nevertheless one of the most natural subdivisions of the cerebral hemisphere. It is not developed in the brain of the quadruped. Man and the ape alone possess a well-marked occipital lobe, and it may be defined as being that part of the hemisphere which encloses the posterior horn of the lateral ventricle. Being pyramidal in form, it presents three surfaces and an apex or occipital pole. On the mesial aspect of the hemisphere it is separated from the parietal lobe (*i.e.* the præcuneus) by the internal parieto-occipital fissure. On the tentorial or inferior surface it is not marked off in any way from the temporal lobe and the limbic lobe, which lie in front of it. It is necessary, therefore, on this aspect to employ an arbitrary line of demarcation; one which extends from the præoccipital notch on the infero-lateral border of the hemisphere to the isthmus of the limbic lobe (*i.e.* the narrow part of the limbic lobe immediately below the hinder end of the corpus callosum) will serve the purpose. On the external surface the external parieto-occipital fissure, and an arbitrary line from this to the præoccipital notch, may be regarded as separating the occipital from the parietal and temporal lobes. The upturned end of the second temporal sulcus may lie in the course of this line.

On the *mesial aspect of the occipital lobe* we find: (1) the calcarine fissure, (2) the cuneus, and (3) the gyrus lingualis.

The **calcarine fissure** begins on the occipital pole by a bifurcated extremity, which lies in the groove which is formed on this part of the brain by the lateral sinus. From this it pursues a slightly arched course forwards, and ends by cutting into the limbic lobe immediately below the splenium or thickened hinder margin of the corpus callosum. The calcarine fissure is joined by the internal parieto-occipital fissure at a point somewhat nearer its anterior than its posterior extremity. Together, the two fissures present a ≺-shaped figure. Between the two limbs of the Y is placed the cuneus.

If the calcarine and internal parieto-occipital fissures are opened up so as to expose the bottom in each case, three well-marked deep or submerged annectant gyri will usually be displayed. One of these, the best marked, called the **gyrus cunei**, marks off the parieto-occipital from

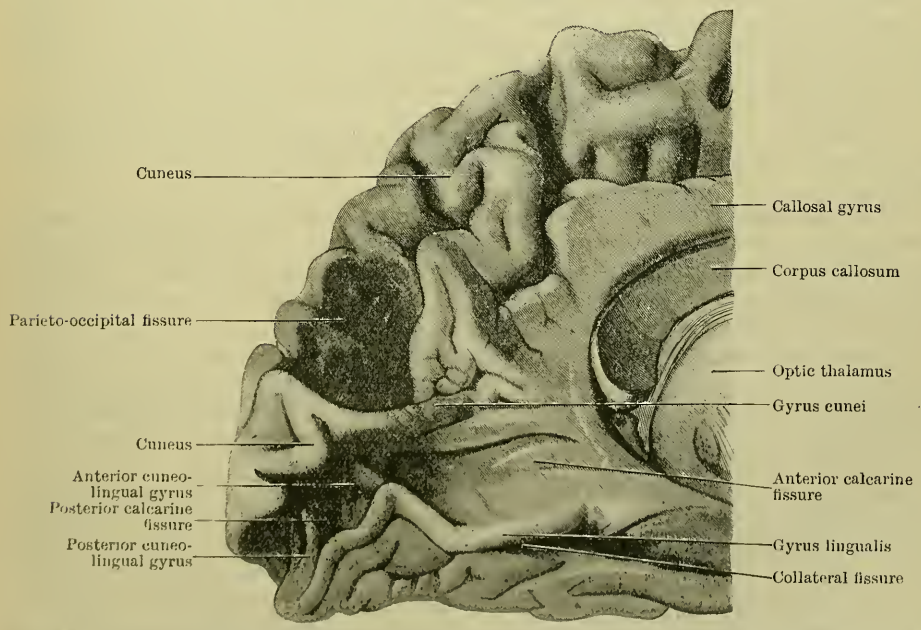


FIG. 454.—INTERNAL PARIETO-OCCIPITAL AND THE CALCARINE FISSURES FULLY OPENED UP, so as to show the deep annectant gyri marking off the several elements of the ≺-shaped system.

the calcarine fissure and joins the cuneus with the limbic lobe. In the chimpanzee and in the lower apes the gyrus cunei is on the surface, and there is no communication between the two fissures; in the orang, gibbon, and microcephalic idiot, it may either be submerged or on the

surface. The second deep annectant gyrus, termed the **anterior cuneo-lingual**, crosses the bottom of the calcarine fissure a short distance behind the point where it is joined by the parieto-occipital fissure, and divides it into an anterior and a posterior part. The **anterior calcarine fissure** is slightly longer and much deeper than the posterior part. It includes the whole of the stem of the Y-shaped fissural arrangement and extends backwards for a short distance into the cuneus. It is the complete part of the fissure and gives rise to an elevation on the inner wall of the posterior horn of the lateral ventricle, to which the name of calcar avis or hippocampus minor is given. The **posterior calcarine fissure** is shallower and is usually interrupted by the third deep annectant gyrus, viz. the **posterior cuneo-lingual**; this divides it into two parts, of which the

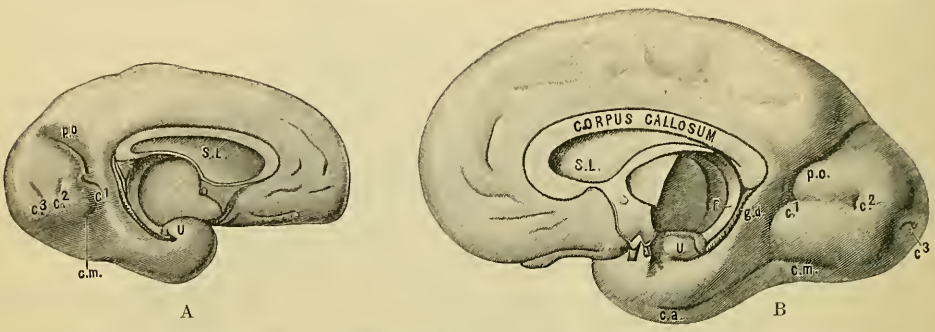


FIG. 455.—DEVELOPMENT OF THE PARIETO-OCCIPITAL AND THE CALCARINE FISSURES.

A, Mesial aspect of a left cerebral hemisphere of a fœtus approaching the end of the fifth month of development; B, Mesial aspect of a right cerebral hemisphere of a fœtus in the beginning of the seventh month of development.

S.L. Septum lucidum.
f. Fornix.
U. Uncus.
g.d. Gyrus dentatus.
p.o. Parieto-occipital fissure.
c^1. Anterior calcarine fissure.
c^2. c^3. Two parts of posterior calcarine fissure.
c.a. Anterior collateral fissure.
c.m. Mid-collateral fissure.

hinder is little more than the bifurcated extremity of the fissure. Very frequently this deep gyrus reaches the surface, and then the hinder end of the sulcus is completely cut off. The posterior calcarine fissure is not a complete fissure.

When the manner in which the calcarine fissure is developed is studied, the various appearances which come into view when the bottom of the adult fissure is inspected receive the fullest explanation. The anterior calcarine fissure is formed very early as an infolding of the wall of the cerebral hemisphere. The posterior calcarine fissure is a secondary formation. It appears much later, and usually in two pieces, which run together and then join the anterior calcarine fissure. The points of union are indicated in the adult by the two cuneo-lingual deep gyri.

The **cuneus** is the wedge-shaped or triangular district, on the mesial aspect of the occipital lobe, which lies between the internal parieto-occipital and calcarine fissures.

The **gyrus lingualis** is a well-marked convolution between the calcarine fissure above and the posterior part of the collateral fissure below, which stretches forwards from the occipital pole. Anteriorly, it becomes very narrow and joins the hippocampal part of the limbic lobe. It lies partly on the mesial surface and partly on the tentorial surface of the occipital lobe.

On the *tentorial surface of the occipital lobe* there is only one convolution, viz. the posterior part of the **occipito-temporal gyrus**. It proceeds continuously forwards into the temporal lobe on the outer side of the collateral fissure, and is bounded externally by the **occipito-temporal sulcus**, a furrow which is rarely continuous, but is usually represented by a series of detached pieces.

There are two well-marked sulci on the *external surface of the occipital lobe*, viz. the sulcus occipitalis transversus and the sulcus occipitalis lateralis. The **sulcus occipitalis transversus** extends transversely across the upper part of the lobe, behind the arcus parieto-occipitalis. As already explained, it is the terminal bifurcation of the ramus occipitalis of the intraparietal sulcus. The **sulcus occipitalis lateralis** is a short horizontal, often sharply-curved, furrow, which divides the outer surface of the lobe into an upper and a lower area of very nearly equal extent. These areas are connected by superficial annectant gyri with the parietal and temporal lobes.

Elliot Smith has brought forward very convincing proof in favour of regarding the sulcus occipitalis lateralis as the representative of the "Affenspalte" in the brain of the

ape. He calls it the **sulcus lunatus occipitalis**, and shows that in the brains of Egyptian Fellaheen it not infrequently possesses an operculum, and presents an appearance which closely corresponds with the condition distinctive of the gorilla. The same may occasionally be seen in the brain of the aboriginal Australian.

Temporal Lobe.—The temporal lobe lies behind the stem and below the posterior horizontal limb of the Sylvian fissure. It is somewhat pyramidal in form, and presents an upper, an outer, and a tentorial surface, with a free projecting apex or pole. Above, it is bounded by the posterior horizontal limb of the fissure of Sylvius, together with the artificial line which is drawn backwards from this. On the tentorial face it is separated from the hippocampal part of the limbic lobe by the collateral fissure, whilst behind it is marked off from the occipital lobe by the artificial lines already described. The temporal pole projects forwards on the under surface of the brain beyond the stem of the Sylvian fissure. It should be noticed that the recurved end of the hippocampal part of the limbic lobe (uncus), which lies to the inner side of the temporal pole, does not extend so far forwards as the latter, and is separated from the pole by the incisura temporalis or ecto-rhinal fissure.

The *upper or opercular surface of the temporal lobe* is turned towards the island of Reil and the fronto-parietal operculum. The fissure of Sylvius must, therefore, be widely opened up to expose it. For the most part the surface is smooth, but towards the back part there are a few transverse furrows, which separate two or three weakly-expressed gyri.

The anterior transverse gyrus is much more strongly expressed in the fœtal than in the adult brain. It appears in the early part of the seventh month, and is only subsequently completely hidden within the Sylvian fissure. The fact of the auditory centre being localised in this region of the temporal lobe makes this fact of interest.

On the deep surface of the temporal pole there are also a few feeble furrows.

On the *outer surface of the temporal lobe* there are two horizontal sulci, called respectively the first temporal or parallel and the second temporal sulcus.

The **parallel sulcus** is a long, continuous, and deep fissure, which begins near the temporal pole and proceeds backwards below the posterior limb of the Sylvian fissure. Its hinder end turns upwards into the parietal lobe and is surrounded by the angular gyrus. The **second temporal sulcus** is placed midway between the parallel sulcus and the infero-lateral border of the hemisphere. It is very rare to find it in the form of a continuous cleft; usually it is broken up into several isolated pieces, one behind the other. Its hinder part, which turns upwards into the parietal lobe, lies close to the artificial line of demarcation between the occipital and parietal lobes, and is surrounded by the postparietal gyrus.

By the two temporal sulci the outer surface of the temporal lobe is mapped out into three tiers of horizontal convolutions, which are termed the **first, second,** and **third temporal gyri.**

On the *tentorial surface of the temporal lobe* there is one fissure, termed the occipito-temporal sulcus. The **occipito-temporal sulcus** lies to the outer side of the collateral fissure and close to the infero-lateral margin of the hemisphere. It runs in an antero-posterior direction, and is not confined to the temporal lobe, but extends backwards towards the occipital pole. It is usually broken up into two or more separate pieces.

The **occipito-temporal convolution** is situated between the collateral fissure and the occipito-temporal sulcus. It extends from the occipital pole behind to the temporal pole in front.

The narrow strip of surface on the outer side of the occipito-temporal sulcus is continuous, round the infero-lateral margin of the hemisphere, with the third temporal convolution on the outer surface of the cerebrum, and may be reckoned as a part of it.

The three temporal convolutions and the occipito-temporal convolutions run into each other at the temporal pole.

Island of Reil or Insula.—The insula is a triangular and somewhat bulging field of cerebral cortex, which lies on a deeper plane than the general surface of the hemisphere and is hidden from view by the four opercula which overlap it. It is circumscribed by a limiting sulcus (sulcus circularis), already described, and its

dependent apical part, which is directed downwards, is in close relation to the anterior perforated spot and the Sylvian vallecula. Here the limiting sulcus is absent and the gray matter on the surface of the insula passes continuously into the anterior perforated spot. The place of transition is called the **limen insulæ**.

The insula is divided into several diverging convolutions by a series of radiating sulci. Of the latter, one, which presents the same direction and lies in the same plane as the fissure of Rolando, receives the name of the **sulcus centralis insulæ** (Fig. 447, C, p. 557). It divides the insula into an anterior *frontal part* and a posterior *parieto-limbic part.*

Limbic Lobe.—This lobe is seen on the mesial surface of the hemisphere in the form of an elongated ring-like convolution, the extremities of which approach closely to each other at the locus perforatus anticus. These extremities are connected by the roots of the olfactory tract, and in this manner the limbic ring may be considered to be closed. The upper part of the limbic lobe is placed in intimate relation to the extremities and upper surface of the corpus callosum, and receives the name of callosal convolution or gyrus fornicatus. The lower portion of the lobe is termed the hippocampal convolution and forms the inner part of the tentorial surface of the hemisphere. The continuity between the hippocampal gyrus and the callosal convolution is established below the hinder end of the corpus callosum by a narrow portion of the limbic lobe, called the isthmus. From this point the hippocampal convolution extends forwards towards the temporal pole. Finally, on the side of the crus cerebri, the hippocampal gyrus is folded back on itself and ends in a recurved hook-like extremity called the uncus. The uncus does not reach so far forwards as the temporal pole.

The **callosal convolution** begins below the anterior end of the corpus callosum at the locus perforatus anticus, and, winding round the genu of the corpus callosum, it is continued backwards on its upper surface to its hinder thickened extremity or splenium. Curving round this, it becomes greatly narrowed through the calcarine fissure cutting into it. This narrow part is termed the **isthmus**, and constitutes the link of connexion between the callosal gyrus and the hippocampal gyrus. The callosal gyrus is separated from the marginal convolution by the calloso-marginal fissure, and behind this it is imperfectly marked off from the præcuneus by the post-limbic sulcus. The furrow which separates it from the corpus callosum is termed the **callosal sulcus.**

The **hippocampal convolution** is bounded on the outer side by the anterior part of the collateral fissure, and in front of this by the incisura temporalis, which separates its hooked extremity, or **uncus**, from the temporal pole. On the inner side it is limited by the hippocampal or dentate fissure, whilst posteriorly it is divided into two parts by the anterior extremity of the calcarine fissure. Of these, the upper is the isthmus, which connects it with the callosal gyrus, whilst the lower portion brings it into continuity with the gyrus lingualis. The surface of the hippocampal convolution is covered by a white reticular stratum of fibres, termed the *substantia reticularis alba.*

Although the hippocampal convolution and uncus in descriptive anatomy are classed together there is a marked morphological distinction between them. The uncus is the feeble representative in man of the important pyriform lobe in certain of the lower mammals, and consequently it belongs to the *rhinencephalon*; the hippocampal convolution, on the other hand, is to be regarded as forming a part of the *neo-pallium* of Elliot Smith. The unimportant incisura temporalis of the human brain in lower types of brain in which the rhinencephalon bulks largely is represented by the conspicuous *ecto-rhinal fissure.*

Gyrus Dentatus and the Fimbria.—If the dentate fissure, which lies along the inner side of the hippocampal convolution, be opened up, the gyrus dentatus and the fimbria, lying side by side, will be brought into view (Fig. 451, p. 559).

The **fimbria** is simply a portion of the posterior pillar of the fornix prolonged into this region. It is a conspicuous band of white matter, which presents a prominent free border. In front it runs into the recurved extremity of the uncus, whilst, if traced backwards, it will be seen to curve upwards behind the posterior end of the optic thalamus and become continuous with the posterior pillar of the fornix below the hinder part of the corpus callosum.

The **gyrus dentatus** is the free edge of gray matter which is placed between the fimbria and the deep part of the upper surface of the hippocampal convolution. The groove between it and the fimbria is termed the **fimbrio-dentate sulcus**, whilst the furrow between it and the hippocampal convolution forms the bottom of the **dentate fissure.** The dentate gyrus is notched along the margin, whilst its surface is scored by numerous parallel and closely-placed transverse grooves. It begins behind in the region of the splenium or thickened posterior margin of the corpus

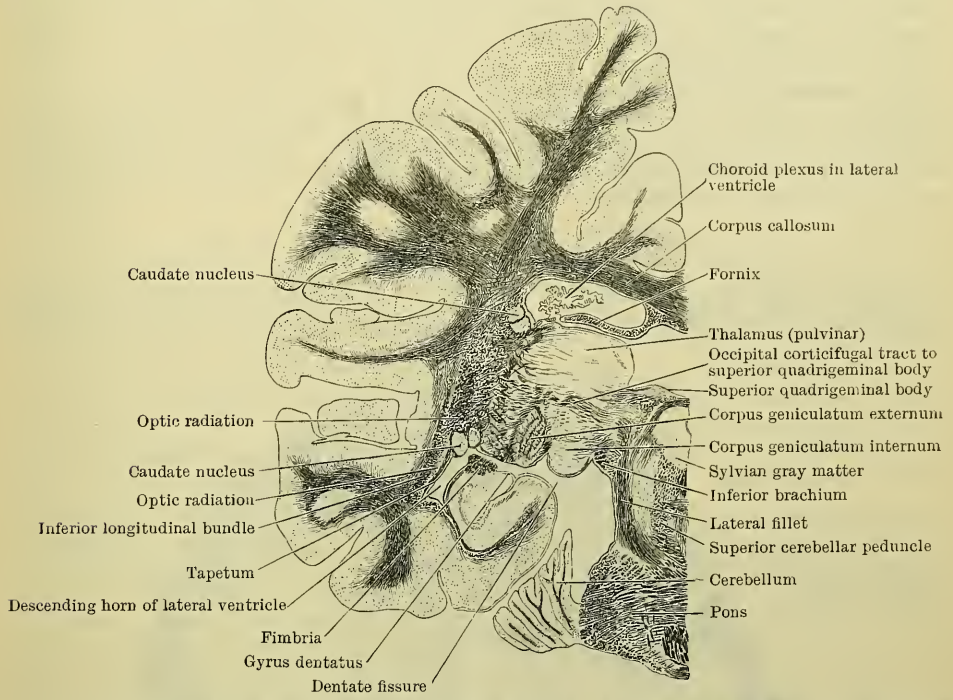


Fig. 456.—Coronal Section through the Left Side of the Cerebrum, Mesencephalon, and Pons, in the Region of the Pulvinar of the Thalamus and the Corpora Geniculata (Chimpanzee ; Weigert-Pal specimen).

callosum, and is carried forwards into the cleft of the uncus. From this it emerges in the form of a delicate band, which crosses the surface of the recurved part of the uncus in a transverse direction, thereby constituting the *frenulum Giacomini.*

The **dentate fissure** is a complete fissure, and the elevation on the ventricular wall which corresponds to it is called the hippocampus major. It begins behind the splenium of the corpus callosum, where it is continuous with a shallow part of the callosal fissure, and it proceeds forwards between the gyrus dentatus and the hippocampal convolution. Its anterior end is enclosed within the uncus.

When coronal sections are made through the callosal part of the limbic lobe and the subjacent corpus callosum, the cortical gray matter is seen to be reflected from the bottom of the callosal fissure in the form of an exceedingly fine layer, which forms a thin coating for the upper surface of the corpus callosum. In the midst of this certain delicate strands of longitudinal fibres, the striæ **longitudinales**, are embedded, and, with the gray matter associated with them, they represent an aborted or vestigial convolution, termed the **gyrus supracallosus.** This gyrus is continuous with the gyrus dentatus round the hinder margin of the corpus callosum.

Olfactory Lobe.—The olfactory lobe is small and rudimentary in the human brain, and the description which is given here does not include all the parts which, from the morphological point of view, belong to this portion of the cerebral hemisphere (see p. 584). Under this heading we shall study merely: (1) the olfactory bulb and tract, with the two roots of the latter; (2) the trigonum olfactorium.

The **olfactory tract** is a narrow, white, prismatic band, which expands anteriorly into a swollen bulbous extremity, termed the **olfactory bulb.** Both the tract and the bulb lie upon the olfactory sulcus on the orbital surface of the frontal lobe,

whilst the inferior surface of the bulb rests on the cribriform plate of the ethmoid bone, and receives the numerous olfactory nerves which reach it through the foramina in that part of the cranial floor.

Posteriorly, the olfactory tract divides into two diverging roots. The **mesial root** curves abruptly inwards and is continued into the callosal and sub-callosal gyri. The **lateral root** runs outwards and backwards over the outer part of the locus perforatus anticus, and gradually disappears from view. In animals, in which the olfactory apparatus is better developed than in man, it may be traced into what corresponds to the uncinate extremity of the hippocampal convolution in man (Fig. 380, p. 474).

The **trigonum olfactorium** or olfactory tubercle is the small triangular field of gray matter which occupies the interval between the roots of the olfactory tract at the point where they begin to diverge. Some fibres from the posterior end of the olfactory tract enter the trigonum, and, in certain cases, these constitute a more or less distinct **middle root.**

Corpus Callosum, Septum Lucidum, and Fornix.

Corpus Callosum.—The corpus callosum is the great transverse commissure which passes between the two cerebral hemispheres. It is placed nearer the anterior

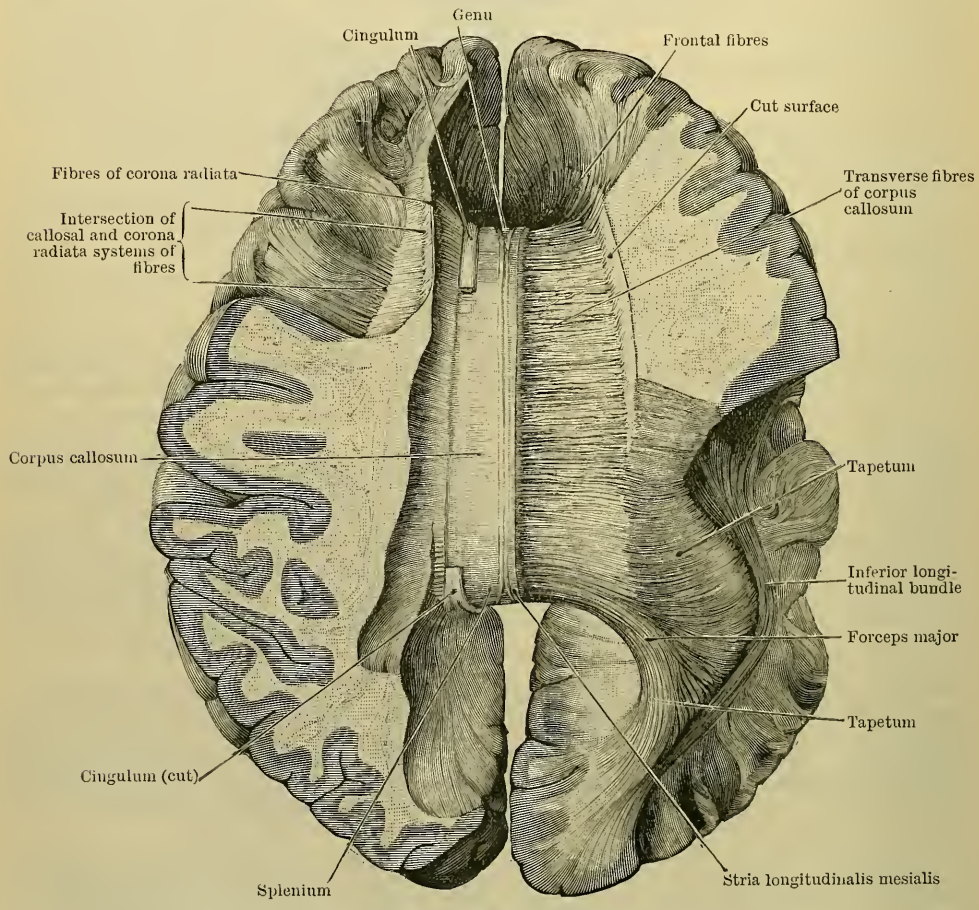


Fig. 457.—The Corpus Callosum, exposed from above and the right half dissected, to show the course taken by its fibres.

than the posterior aspect of the brain, and it unites the inner surfaces of the hemispheres throughout very nearly a half of their antero-posterior length. The corpus callosum is highly arched from before backwards, and presents a convex upper surface and a concave lower surface.

The *upper surface* of the corpus callosum forms the bottom of the great longitudinal fissure, and on each side of this it is covered by the callosal gyrus. Only in its posterior part is it touched by the falx cerebri; in front, this process of dura mater falls considerably short of it. The upper surface of the callosum is covered by a thin layer of gray matter continuous at the bottom of the callosal sulcus with the gray cortex on the surface of the hemisphere. In this there are embedded on either side of the mesial plane two delicate longitudinal bands of fibres, called respectively the stria longitudinalis medialis and lateralis. The **stria longitudinalis medialis** is the more strongly marked of the two, and it is separated from its neighbour of the opposite side by a faint mesial furrow. The **stria longitudinalis lateralis** is placed farther out, under cover of the callosal gyrus. The thin coating of gray matter, with the two striæ, represents an aborted convolution, termed the **gyrus supracallosus.** So thin is the gray coating supplied by this gyrus that the transverse direction pursued by the callosal fibres proper can be easily perceived through it.

The two extremities of the corpus callosum are much thickened, whilst the intermediate part or **body** is considerably thinner. The massive *posterior end*, which is full and rounded, lies over the mesencephalon and extends backwards as far as the highest point of the cerebellum. It is called the **splenium,** and it consists of an upper and a lower part. The latter is bent forwards under the upper part, to the inferior surface of which it is closely applied. The *anterior end* of the corpus callosum is not quite so massive and is folded downwards and backwards on itself. It is termed the **genu.** The recurved lower part of the genu is separated from the part of the corpus callosum, which lies above, by an interval. It rapidly thins as it passes backwards and receives the name of the **rostrum.** The fine terminal edge of the rostrum becomes connected with the lamina cinerea.

The gyrus supracallosus, with its contained medial and lateral longitudinal striæ, when traced backwards, is seen to turn round the splenium and become continuous with the gyrus dentatus. In front the mesial striæ, with the associated gray matter, are carried round the genu and then backwards on the under surface of the rostrum. As they turn round the anterior extremity of the corpus callosum, each stria runs into the corresponding **gyrus subcallosus**—a narrow cortical strip which lies on the mesial surface of the hemisphere immediately below the genu of the corpus callosum. The gyrus subcallosus is often called the peduncle of the corpus callosum, and the fibres of the stria which it contains, emerging from its substance, proceed backwards and outwards along the posterior limit of the anterior perforated spot towards the anterior extremity of the temporal lobe. Elliot Smith has shown that these parts have an important morphological significance.

The *under surface* of the corpus callosum on either side of the mesial plane is for the most part free, and, lined by ependyma, it forms the roof of the anterior horn and body of the lateral ventricle. In the mesial plane, however, it is attached to subjacent parts, viz. to the septum lucidum in front and to the body of the fornix behind.

The transverse fibres of the corpus callosum, as they enter the white medullary centre of the cerebral hemisphere, radiate from each other so as to reach every part of the cerebral cortex. This radiation is termed the **radiatio corporis callosi** and the fibres which compose it intersect the fibres which form the corona radiata, or, in other words, the fibres which extend between the internal capsule and the cerebral cortex (Figs. 440, p. 547; and 468, p. 582). The more anterior of the fibres which compose the genu of the corpus callosum sweep forwards in a series of curves into the prefrontal region of the hemisphere. A large part of the splenium, forming a solid bundle termed the **forceps major**, bends suddenly and abruptly backwards into the occipital lobe (Fig. 463, p. 577). Fibres from the body and upper part of the splenium, curving round the lateral ventricle, form a very definite stratum, called the **tapetum.** This is a thin layer in the medullary centre of the hemisphere, which constitutes the immediate roof and outer wall of the posterior horn and the outer wall of the hinder part of the descending horn of the lateral ventricle. In coronal sections through the occipital and hinder temporal regions the tapetum stands out very distinctly (Figs. 456, p. 569; 462, p. 576; and 465, p. 579).

Fornix.—The fornix is an arched bilateral structure composed, for the most part, of longitudinally-directed fibres. In its intermediate part its two lateral

halves are joined together in the mesial plane, and form what is called the body of the fornix; but in front and behind they are quite separate, and constitute the anterior and posterior pillars of the fornix.

The **body of the fornix** is triangular in form. In front, where it is continuous with the anterior pillars, it is narrow; whilst behind it broadens out, becomes flattened, and is finally prolonged into the posterior pillars. The upper surface of the body of the fornix is in contact with the under surface of the hinder part of the body of the corpus callosum, and posteriorly is adherent to it. In front of this adhesion, and in the mesial plane, it is attached to the septum lucidum. Beyond these attachments, on each side, the upper surface of the body of the fornix forms a part of the floor of the lateral ventricle and is clothed by the lining ependyma. It presents a sharp lateral edge or margin, from under which the choroid plexus projects into the cavity of the lateral ventricle and with which the epithelial layer which covers that plexus is continuous. The lower surface of the body of the fornix rests upon the velum interpositum, which separates it from the roof of the third ventricle and the upper surface of the optic thalami. It is not at all an uncommon occurrence to find the two lateral portions of the body of the fornix of unequal size (Fig. 461, p. 575).

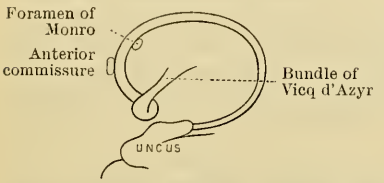


FIG. 458.—DIAGRAMMATIC PROFILE VIEW OF THE FORNIX.

The **anterior pillars of the fornix** (columnæ fornicis) are two rounded strands which emerge from the anterior part of the body of the fornix, and then diverge very slightly from each other as they curve downwards in front of the foramina of Monro. Sinking into the gray matter on the lateral wall of the third ventricle, each anterior pillar proceeds downwards to the base of the brain, and in the interpeduncular space protrudes, to take part in the formation of the corpus mammillare. When the corpus mammillare is dissected it appears to be largely formed of a twisted loop of the anterior pillar of the fornix, in which the pillar bends upon itself, and is then continued upwards and backwards into the optic thalamus. This appearance, however, is misleading. The fibres of the anterior pillar end in the gray nucleus of the corpus mammillare, and the strand which passes from this to the thalamus is the **bundle of Vicq d'Azyr** (p. 548).

The **posterior pillars of the fornix** (crura fornicis) are flattened bands which diverge widely from each other. At first they are adherent to the under surface of the corpus callosum, but soon they sweep downwards round the posterior ends of the optic thalami and enter the descending horns of the lateral ventricles. Here each pillar comes into relation with the corresponding hippocampus major, and a portion of its fibres are spread out on the surface of this prominence, thereby giving it a white coating termed the **alveus**, whilst the remainder of the fibres constitute the **fimbria** or **tænia fornicis**—a narrow but very distinct band of white matter, which is attached by its outer margin along the inner border of the hippocampus major and ends in front by joining the uncus (p. 568).

A certain number of transverse fibres enter into the formation of the fornix. The diverging posterior pillars enclose between them a small triangular space on the under surface of the hinder part of the corpus callosum. This area is crossed by transverse fibres, which form a thin lamina called the **psalterium** or **lyra**. Sometimes the psalterium is not completely fused to the under surface of the corpus callosum, and in these cases a narrow space is left between them, which receives the name of **Verga's ventricle.**

The fornix is intimately connected with the olfactory apparatus. Its fibres for the most part, arise from the pyramidal cells in the cornu ammonis or hippocampus major and ascend in the fimbria and posterior pillar. In the region of the psalterium numerous fibres cross the mesial plane, enter the opposite posterior pillar, and in it proceed to the opposite cornu ammonis. These fibres constitute a commissure between the two cornua ammonis. The remainder of the fibres proceed forwards in the body of the fornix, and by means of the anterior pillar the majority of the fibres are carried downwards, behind the anterior commissure, to the corpus mammillare. Some, however, curve backwards into the stria medullaris (p. 548); whilst others, forming the **olfactory bundle of the cornu ammonis**, pass in front of the anterior commissure and

enter the septum lucidum, through which they reach the subcallosal gyrus and the locus perforatus anticus. Finally, this bundle divides into two parts, of which one joins the inner root of the olfactory tract, whilst the other goes to the uncus.

The greater number of the longitudinal fibres of the fornix must, therefore, be regarded as establishing a connexion between the cornu ammonis and the optic thalamus. The inner portion of the composite nucleus of the corpus mammillare is an internode interposed in the path of this connecting tract. The bundle of Vicq d'Azyr, formed by the relay of fibres which takes origin in this internode, forms the second link in the chain.

The striæ longitudinales in the gyrus supracallosus on the upper surface of the corpus callosum are to be regarded, from a morphological point of view, as forming an outlying part of the fornix system.

There can be little doubt that the gyrus supracallosus represents a wasted portion of the hippocampus formation. In monotremes and marsupials the hippocampus occupies a corresponding position, but, with the greater development of the corpus callosum in higher mammals, atrophy and stretching occur and the structure is reduced to a vestigial condition (Elliot Smith). That fornix fibres therefore should be found in connexion with the supracallosal gyrus is not surprising.

Septum Lucidum (septum pellucidum).—The septum lucidum is a thin vertical partition which intervenes between the anterior cornua and foreparts of the bodies of the two lateral ventricles. It is triangular in shape, and posteriorly it is prolonged backwards for a variable distance between the body of the corpus callosum and the fornix, to both of which it is attached by its upper and lower edges. In front it occupies the gap behind the genu of the corpus callosum, whilst below, in the narrow interval between the posterior edge of the rostrum of the corpus callosum and the fornix, it is prolonged downwards towards the base of the brain in the gyrus subcallosus. The septum lucidum is composed of two thin laminæ in apposition with each other in the mesial plane (Fig. 461, p. 575).

Fifth Ventricle (cavum septi pellucidi).—This name is applied to the mesial cleft between the two laminæ of the septum lucidum. It varies greatly in size in different brains and contains a little fluid. It is completely isolated and presents no communication with the other ventricles of the brain. Indeed, the term "ventricle," as applied to it, is quite inappropriate, seeing that at no period in the development of the brain has it any connexion with the general ventricular system.

Lateral Ventricle.

The cavity in the interior of the cerebral hemisphere is called the lateral ventricle. It is lined throughout by ependyma continuous with the ependymal lining of the third ventricle. In many places the walls of the cavity are in apposition, whilst in other localities spaces of varying capacity, and containing cerebro-spinal fluid, are left between the bounding walls.

The **lateral ventricle** (ventriculus lateralis) communicates with the third ventricle of the brain by means of a small foramen, just large enough to admit a crow-quill, which is termed the **foramen of Monro**. This aperture is placed in front of the fore end of the optic thalamus and behind the anterior pillar of the fornix.

The highly-irregular shape of the lateral ventricle can be best understood by the study of a cast of its interior (Figs. 459; and 444, p. 551). It is usual to describe it as being composed of a body and three horns, viz. an anterior, a posterior, and a descending horn. The **anterior horn** is that part of the cavity which lies in front of the foramen of Monro. The **body** is the portion of the ventricle which extends from the foramen of Monro to the splenium of the corpus callosum. At this point the posterior and descending horns diverge from the hinder part of the body. The **posterior horn** curves backwards and inwards into the occipital lobe. It is very variable in its length and capacity. The **descending horn** proceeds with a bold sweep round the hinder end of the optic thalamus, and then tunnels in a forward and inward direction through the temporal lobe towards the temporal pole. The early fœtal lateral ventricle is very capacious and presents an arched or semilunar form. It is composed of parts which correspond to the anterior horn, the body, and the descending horn, and there is little or no demarcation between them. The posterior horn is a later production. It comes into existence with the occipital lobe and is produced as a diverticulum or elongated pouch, which grows backwards from the upper and hinder part (*i.e.* the convexity) of the primitive cavity.

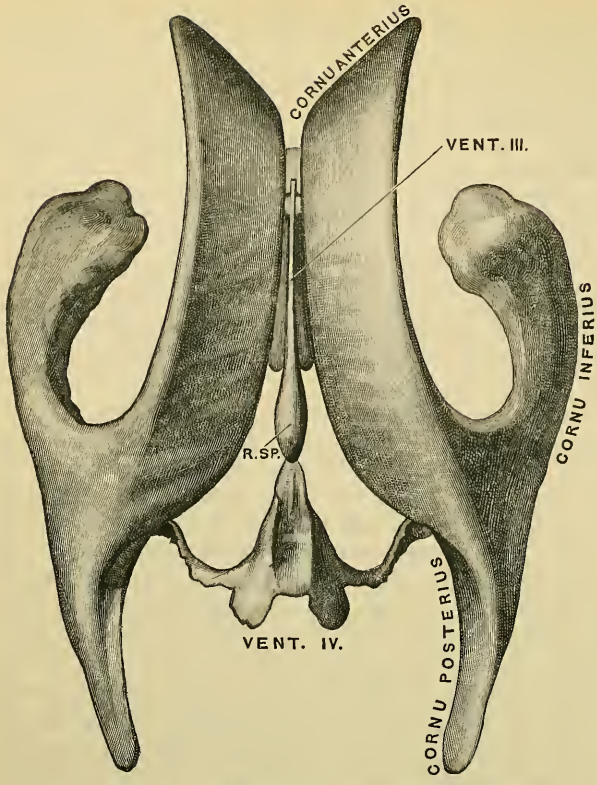


FIG. 459.—DRAWING TAKEN FROM A CAST OF THE VENTRICULAR SYSTEM OF THE BRAIN, as seen from above (after Retzius).

Vent. III. Third ventricle. Vent. IV. Fourth ventricle.
R.SP. Recessus suprapinealis.

Anterior Horn of the Lateral Ventricle (cornu anterius). — The anterior horn forms the foremost part of the cavity, and extends in a forward and outward direction in the frontal lobe. When seen in coronal section (Fig. 460) it presents a triangular outline, the floor sloping upwards and outwards to meet the roof at an acute angle. It is bounded *in front* by the posterior surface of the genu of the corpus callosum; the *roof* is also formed by the corpus callosum. The *inner wall*, which is vertical, is formed by the septum lucidum; whilst the sloping *floor* presents a marked elevation or bulging, viz. the smooth, rounded, and prominent extremity of the pear-shaped caudate nucleus.

Body of the Lateral Ventricle (pars centralis).—The body of the cavity is likewise *roofed* by the corpus callosum. On the *inner* or *mesial side* it is bounded by the attachment of the fornix to the under surface of the corpus callosum and by the hinder part of the septum lucidum. On the *outer side* it is closed, as in the case of the anterior horn, by the meeting of the floor and the roof of the cavity. On the *floor* a number of important objects may be recognised. From without inwards these are met in the following order: (1) the caudate nucleus; (2) a groove which extends obliquely from before backwards and outwards between the caudate nucleus and the optic thalamus, and in which are placed the vein of the corpus striatum and a white band called the tænia semicircularis; (3) a portion of the upper surface of

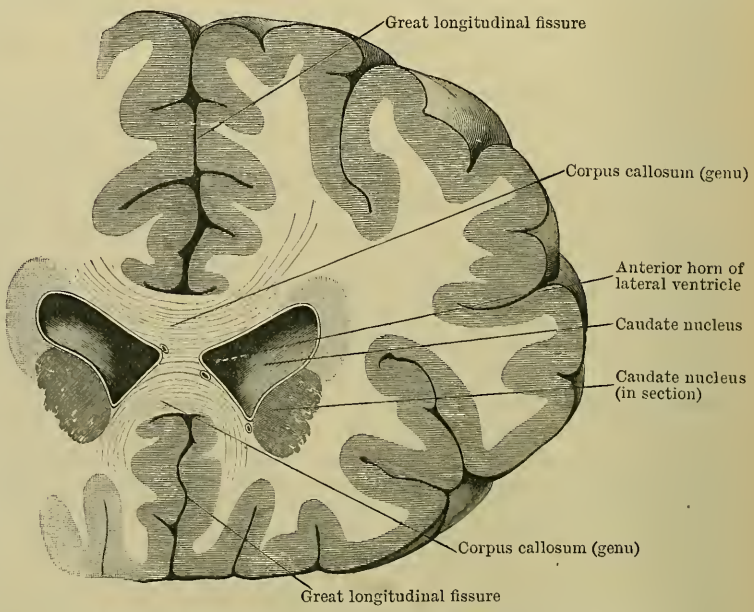


FIG. 460.—CORONAL SECTION THROUGH THE FRONTAL LOBES AND THE ANTERIOR HORNS OF THE LATERAL VENTRICLES.

the optic thalamus; (4) the choroid plexus; (5) the thin, sharp lateral edge of the fornix.

The **caudate nucleus** narrows rapidly as it proceeds backwards on the outer part of the floor of the body of the lateral ventricle. The **vein of the corpus striatum** is covered over by ependyma. It joins the vein of Galen close to the foramen of Monro. The connexions of the **tænia semicircularis** will be dealt with later. The portion of the upper surface of the **optic thalamus** which appears in the floor of the

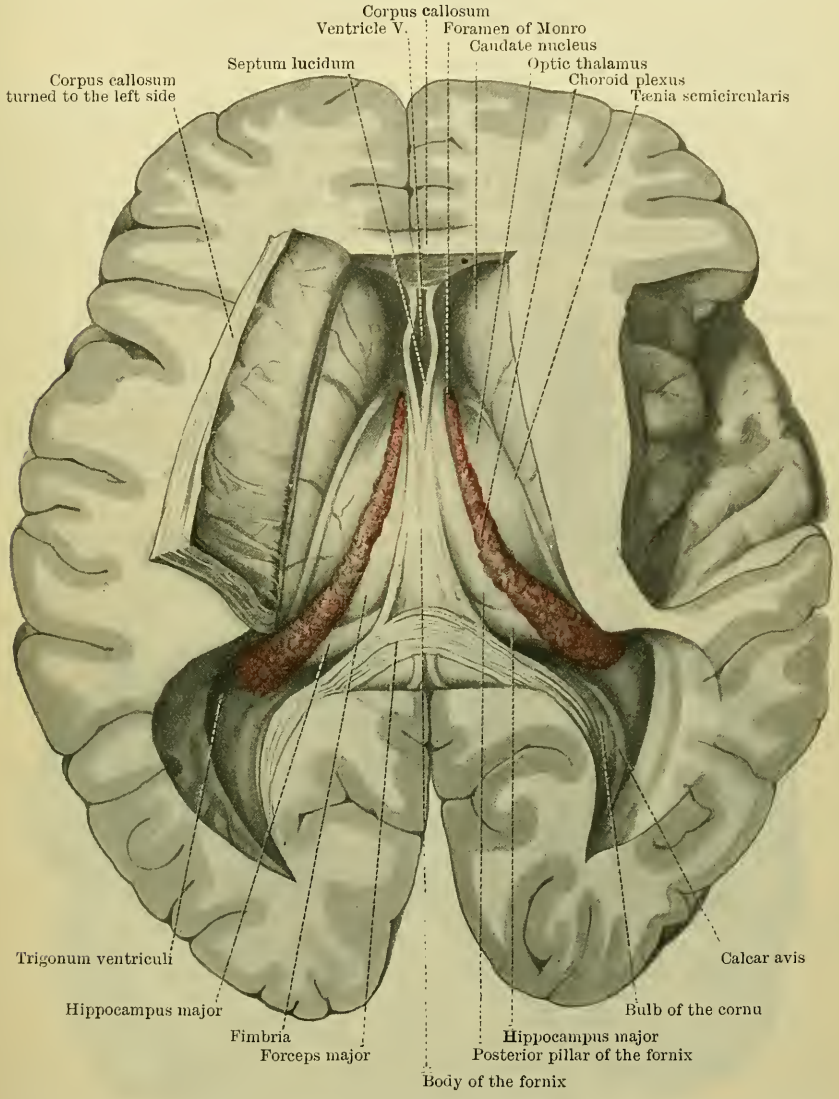


FIG. 461.—DISSECTION, to show the fornix and lateral ventricles; the body of the corpus callosum has been turned over to the left.

ventricle is in great part hidden by the choroid plexus, which lies upon it. The **choroid plexus** is a rich vascular fringe which appears from under cover of the sharp lateral edge of the fornix. In front it is continuous, behind the foramen of Monro, with the corresponding choroid plexus of the opposite side, whilst behind, it is carried into the descending horn of the ventricle. Although the choroid plexus has all the appearance of lying free within the ventricle, it must be borne in mind that it is invested by an epithelial layer which represents a portion of the hemisphere wall and excludes it from the cavity. This thin layer is continuous on the

one hand with the sharp edge of the fornix, and on the other it is attached to the upper surface of the optic thalamus.

Posterior Horn of the Lateral Ventricle (cornu posterius).—The posterior horn is an elongated diverticulum carried backwards into the occipital lobe from the hinder end of the body of the ventricle. It tapers to a point and describes a gentle curve, the convexity of which is directed outwards. The *roof* and *outer wall* of this portion of the ventricular cavity are formed by the tapetum of the corpus callosum. In coronal sections through the occipital lobe this is seen as a thin but distinct layer of white fibres, which lies immediately outside the ependyma and to the inner side of a much larger strand of fibres in the medullary substance of the occipital lobe, viz. the optic radiation.

On the *inner wall* two elongated curved elevations may be observed. The uppermost of these is termed the **bulb of the cornu** (bulbus cornu posterioris), and is produced by the fibres of the forceps major of the corpus callosum as they curve abruptly backwards from the lower part of the splenium of the corpus callosum into the occipital lobe. Below this is the elevation known as the **calcar avis**. It varies greatly in size in different brains, and is caused by an infolding of the ventricular wall in correspondence with the anterior calcarine fissure on the exterior of the hemisphere.

Descending Horn of the Lateral Ventricle (cornu inferius).—The descending horn is the continuation of the cavity into the temporal lobe. At first directed backwards and outwards the descending horn suddenly sinks downwards behind the optic thalamus into the temporal lobe, in the centre of which it takes a curved course forwards and inwards to a point about an inch behind the extremity of the temporal pole.

In the angle between the diverging posterior and descending horns the cavity of the ventricle presents an expansion of a somewhat triangular shape. To this the name of **trigonum ventriculi** is sometimes given.

The *roof* of the descending horn is formed for the most part by the tapetum of

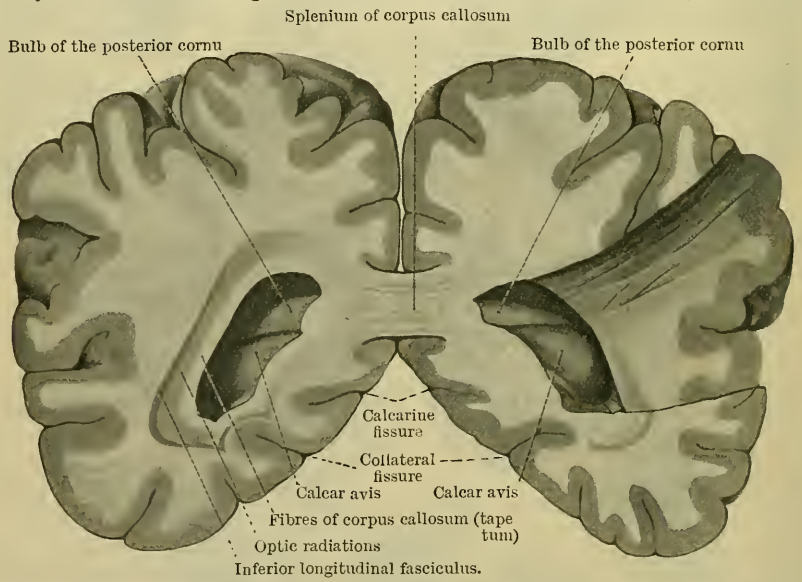


FIG. 462.—CORONAL SECTION THROUGH THE POSTERIOR HORNS OF THE LATERAL VENTRICLES.

the corpus callosum. At the extremity of the horn the roof presents a bulging into the cavity. This is the **amygdaloid tubercle**, and it is produced by a superjacent collection of gray matter termed the amygdaloid nucleus. The **tænia semicircularis** and the attenuated **tail of the caudate nucleus** are both prolonged into the descending horn and are carried forwards, in its roof, to the amygdaloid nucleus.

On *the floor* of the descending horn the following structures are seen: (1) hippocampus major, or the cornu ammonis; (2) the choroid plexus; (3) the fimbria; and (4) the eminentia collateralis.

The **hippocampus major** (hippocampus) is for the most part covered by the

choroid plexus. It is a prominent elevation on the floor of the descending horn of the lateral ventricle and is strongly curved, in conformity with the course taken by the horn in which it lies. It therefore presents an internal concave margin and an external convex border. Narrow behind, it enlarges as it is traced forwards, and it ends below the amygdaloid tubercle in a thickened extremity, which presents some faint grooves or notches on its surface. In consequence of this, the anterior end of the hippocampus major receives the name of the **pes hippocampi**. The hippocampus major is the internal elevation which corresponds to the dentate fissure on the exterior of the hemisphere (Fig. 464).

If an incision be made along the outer convex edge of the hippocampus major, and the surface lamina be raised, the central core will be seen to present the curious appearance of two corrugated layers dove-tailed into each other (M'Carthy).

The **fimbria** (fimbria hippocampi) is the narrow band of white matter which is attached by its outer margin along the inner concave border of the hippocampus major. The white matter composing it is continuous with the thin white layer (the alveus) which is spread over the surface of the hippocampus major, and it presents two free surfaces and a sharp free inner border. The fimbria has already been examined in connexion with the hippocampal fissure and the gyrus dentatus

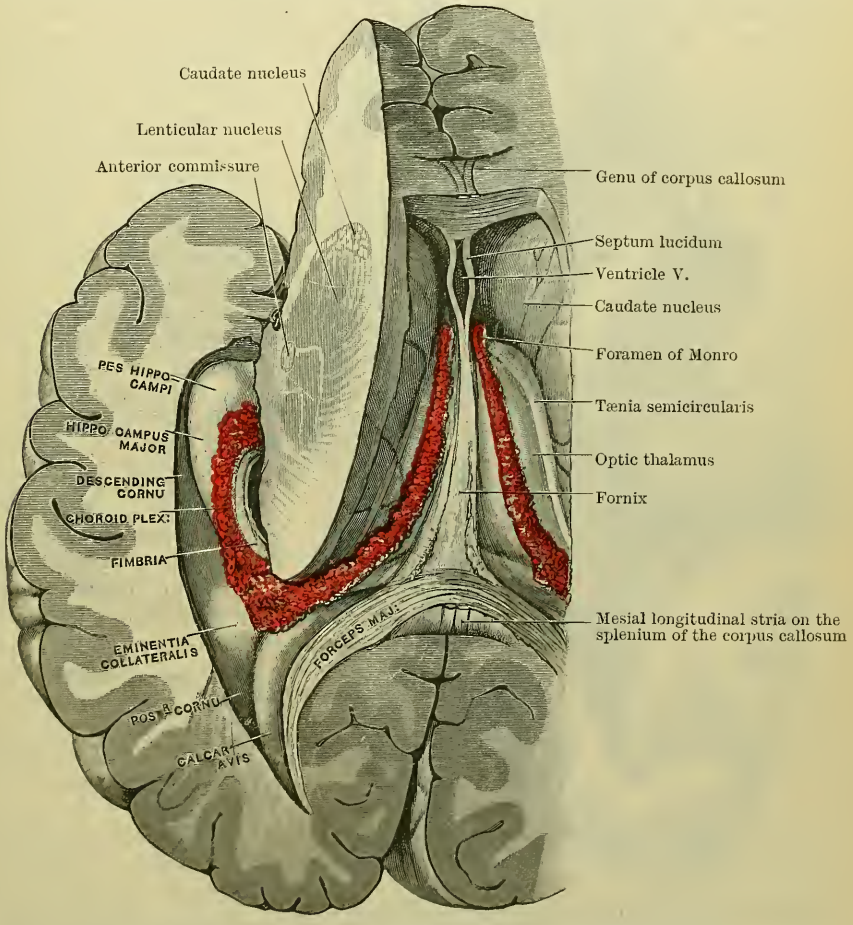


Fig. 463.—Dissection, to show the fornix and the posterior and descending cornua of the lateral ventricle of the left side.

(p. 568), and the relations which it presents to the fornix and the uncus have been pointed out.

When the pia mater in the region of the hippocampal fissure is removed from the surface of the brain, the choroid plexus in the interior of the descending horn

of the lateral ventricle is usually withdrawn with it, and a fissure appears between the fimbria and the roof of the ventricular horn. This is the **choroid fissure.** It appears at a very early date in the development of the cerebral hemisphere, and takes an arcuate course upwards and forwards round the hinder end of the optic thalamus. In the region of the body of the lateral ventricle it extends as far forwards as the foramen of Monro, and is formed by the involution of an epithelial part of the wall of the ventricle over the choroid plexus (p. 575). In the region of the descending horn, when the choroid plexus with the involuted epithelial layer which covers it is withdrawn, the choroid fissure is converted into an artificial gap which leads directly into this part of the ventricular cavity.

The **choroid plexus** is a convoluted system of blood-vessels in connexion with a fold of pia mater, which is prolonged into the descending horn of the lateral ventricle. It lies on the surface of the hippocampus major and is continuous behind the posterior part of the optic thalamus, with the choroid plexus in the body of the lateral ventricle. But it must not be supposed that the choroid plexus lies free in the ventricular cavity. It is clothed in the most intimate manner by an epithelial layer, which represents the inner or mesial wall of the descending horn involuted into the cavity over the choroid plexus. The ventricle, therefore, only opens on the surface through the choroid fissure when this thin epithelial layer is torn away by the withdrawal of the choroid plexus. From the above, it will be understood that the arcuate choroid fissure, throughout its whole length (viz. from the foramen of Monro to the extremity of the descending horn of the lateral ventricle), is formed by the involution of a portion of the wall of the hemisphere which remains epithelial. In the body of the ventricle this layer is attached, on the one hand, to the sharp lateral margin of the fornix, and on the other to the upper surface of the optic thalamus; in the descending horn it is attached, in like manner, to the edge of the fimbria or posterior pillar of the fornix, whilst above it joins the roof of this portion of the ventricle along the line of the tænia semicircularis.

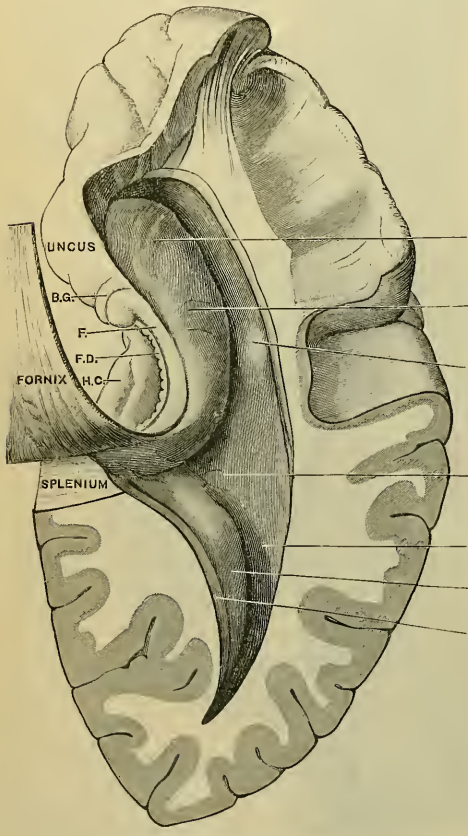


FIG. 464.—DISSECTION from above, to show the posterior and descending cornua of the lateral ventricle.

B.G. Giacomini's band. F.D. Gyrus dentatus.
F. Fimbria. H.C. Hippocampal convolution.

The **eminentia collateralis** shows very great differences in its degree of development, and it may present two distinct forms, which may be distinguished from each other as the eminentia collateralis posterior and the eminentia collateralis anterior.

The *posterior collateral eminence* is a smooth elevation in the floor of the trigonum ventriculi, in the interval which is left between the calcar avis and the hippocampus major as they diverge from each other. In the fœtal brain this is always a very strongly-marked elevation, which corresponds with the mid-collateral fissure, but in the course of growth it is apt to lose much of its prominence.

The *anterior collateral eminence* is only occasionally present. It appears as an elongated elevation of varying length and prominence, on the floor of the descending horn of the lateral ventricle, on the outer side of the hippocampus major. It is formed by the anterior portion of the fœtal collateral sulcus, when this develops as a complete fissure.

Basal Ganglia of the Cerebral Hemisphere.

Under this heading are included certain masses of gray matter more or less completely embedded in the white medullary substance of the hemisphere, and which are developed in its wall. They compose the caudate and lenticular nuclei, which together form the corpus striatum, the claustrum, and the amygdaloid nucleus.

The **caudate nucleus** bulges into the lateral ventricle. It is a pyriform, highly-arched mass of gray matter, which presents a thick, swollen head, or anterior extremity, and a long, attenuated tail. The head projects into the anterior horn of the lateral ventricle, whilst its narrower part is prolonged outwards and backwards in the floor of the body of the ventricle, where it is separated from the optic thalamus by the tænia semicircularis. Finally, its tail curves downwards with a bold sweep and enters the descending horn of the lateral ventricle. In the roof of this horn it is prolonged forwards to the amygdaloid nucleus, the lower part of which it joins. The caudate nucleus thus presents a free ventricular surface, covered with ependyma, and a deep surface embedded in the white substance of the cerebral hemisphere, and for the most part related to the internal capsule.

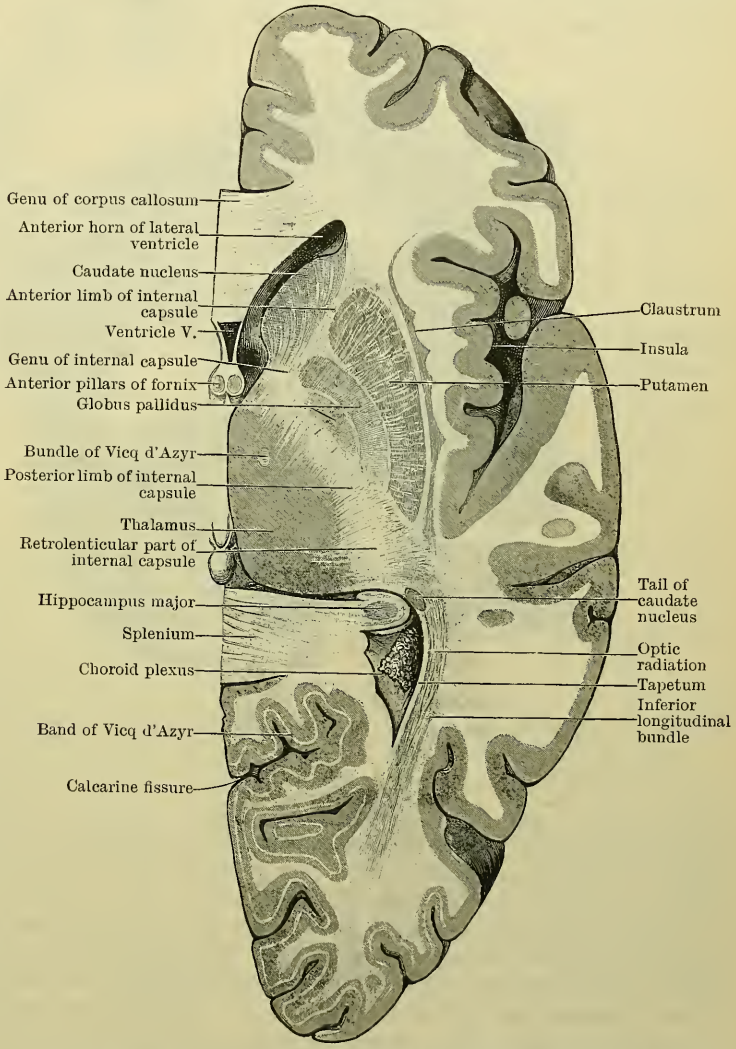


Fig. 465.—Horizontal Section through the Right Cerebral Hemisphere at the Level of the Widest Part of the Lenticular Nucleus.

Owing to its arched form it follows that, in horizontal sections through the cerebral hemisphere below a particular level, it is cut at two points, and both the head and the tail appear on the field of the section (Fig. 465). In coronal sections behind the amygdaloid nucleus, it is also divided at two places (Fig. 440, p. 547).

The anterior extremity of the head of the caudate nucleus coincides very nearly with that of the anterior horn of the lateral ventricle. In the region of the locus perforatus anticus, the head of the caudate nucleus gains the surface and its gray matter becomes continuous with that of the cerebral cortex.

The **lenticular nucleus** lies on the outer side of the caudate nucleus and optic thalamus, and is for the most part embedded within the white medullary substance of the cerebral hemisphere. It does not extend either so far forwards or so far backwards as the caudate nucleus. Indeed, it presents a very close correspondence in point of extent with the insula or island of Reil on the surface. When seen in horizontal section, it presents a shape similar to that of a biconvex lens. Its inner surface bulges more than the outer surface, and its point of highest convexity is placed opposite the tænia semicircularis or the interval between the caudate nucleus and the optic thalamus. In coronal section the appearance presented by the lenticular nucleus differs very much in different planes of section. Fig. 466 represents a section through its anterior portion. Here it is semilunar or crescentic in outline and is directly continuous below with the head of the caudate nucleus; above, also, it is intimately connected with the caudate nucleus by bands of gray matter, which pass between the two nuclei and break up the white matter of the forepart of the intervening internal capsule. It is due to the ribbed or barred appearance, which is presented by such a section as this, that the term **corpus striatum** is applied to the two nuclei. In the region of the locus perforatus anticus both nuclei reach the surface and become continuous with the cortex.

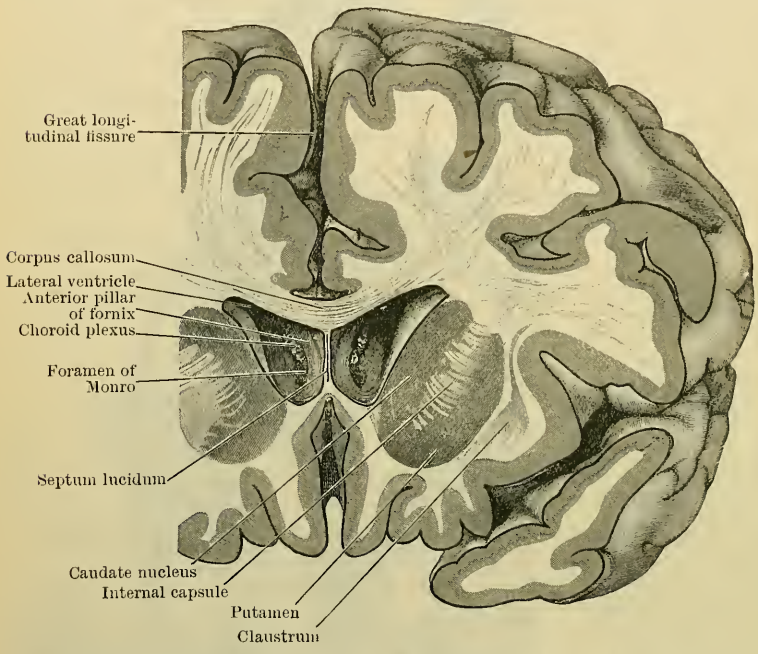


FIG. 466.—CORONAL SECTION THROUGH THE CEREBRAL HEMISPHERES so as to cut through the anterior part (putamen) of the lenticular nucleus in front of the globus pallidus.

When a section is made in a plane further back (*e.g.* immediately posterior to the anterior commissure, as in Fig. 467) the divided lenticular nucleus assumes an altogether different shape, and is seen to be completely cut off from the caudate nucleus by the internal capsule. It is now triangular or wedge-shaped. Its *base* is turned towards the island of Reil and is in direct relation to a thin lamina of white matter, termed the external capsule. Its *internal surface* is oblique and is applied to the internal capsule, whilst its *inferior surface* is horizontal and is directed downwards towards the base of the brain. But, further, two white laminæ, the **external** and **internal medullary laminæ**, are now evident, which traverse its substance in a vertical direction and divide it into three zones. The outer, basal, and larger zone is termed the **putamen**; the two inner portions together constitute the **globus pallidus.**

The **putamen** forms much the largest part of the lenticular nucleus. It is darker in colour than the globus pallidus, and in this respect resembles the caudate nucleus. It is traversed by fine radiating bundles of fibres, which enter it from the

external medullary lamina. Both in point of structure and in mode of development it is closely associated with the caudate nucleus, and it is the only part of the lenticular nucleus which is connected by intervening bands of gray matter with the caudate nucleus. The antero-posterior length, as well as the vertical depth of the putamen, is much greater than in the case of the globus pallidus; consequently, in

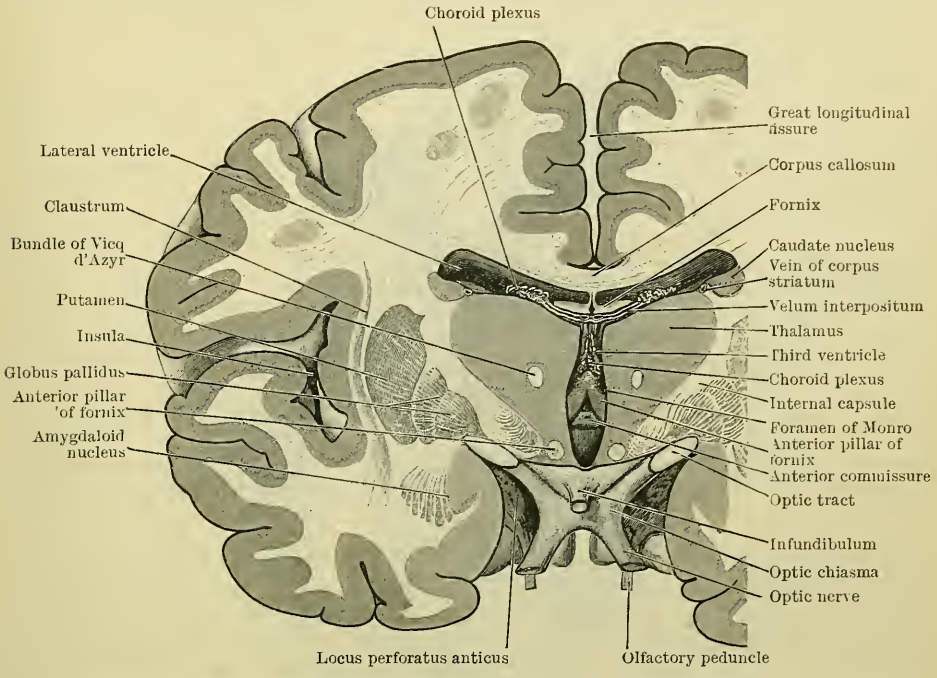


FIG. 467.—CORONAL SECTION THROUGH THE CEREBRUM so as to cut through the three divisions of the lenticular nucleus; posterior surface of the section depicted.

both coronal and horizontal sections through the cerebrum it is encountered before the plane of the globus pallidus is reached.

The external capsule is loosely connected with the outer surface of the putamen, and it can be readily stripped off. This accounts for the tendency, exhibited in hæmorrhages in this locality, for the effused blood to spread out in the interval between these structures.

The **globus pallidus** is composed of the two smaller and inner zones of the lenticular nucleus. They present a faint yellowish tint, and are paler and more abundantly traversed by fibres than the putamen. The zone next the putamen (*i.e.* the intermediate zone) is much larger than the innermost subdivision. It extends forwards to a point a little in front of the plane of the anterior commissure. When the lenticular nucleus is cut in a coronal direction, and in its widest part, the innermost zone shows an indication of a separation into two parts, so that here the globus pallidus appears to consist of three subdivisions. The morphology of the globus pallidus is by no means clear.

Connexions of the Corpus Striatum.—(1) Numerous fibres pass from the optic thalamus to the corpus striatum, and in the reverse direction from the corpus striatum into the thalamus through the anterior limb of the internal capsule. These may be termed the **thalamo-striate** and the **strio-thalamic fibres**. (2) Edinger describes a connexion between the caudate nucleus and the substantia nigra. The connecting fibres pass through the subthalamic region and constitute a tract in the mesencephalon, in close apposition with the substantia nigra, called the **stratum intermedium**. (3) The **ansa lenticularis** has previously been mentioned. It is composed of fibres which come from the inferior part of the fore portion of the thalamus and curve outwards under the lenticular nucleus. They stream upwards into this and through its medullary laminæ. Many of them apparently proceed onwards to the cerebral cortex. (4) Fibres from the posterior

limb of the internal capsule (thalamic fibres chiefly) enter the lenticular nucleus and stream through it, and its medullary laminæ, on their way to the cerebral cortex.

Claustrum.—This is a thin plate of gray substance embedded in the white matter, which intervenes between the lenticular nucleus and the gray cortex of the insula or island of Reil. Followed in an upward direction, it becomes gradually thinner and ultimately disappears. As it is traced downwards, however, it

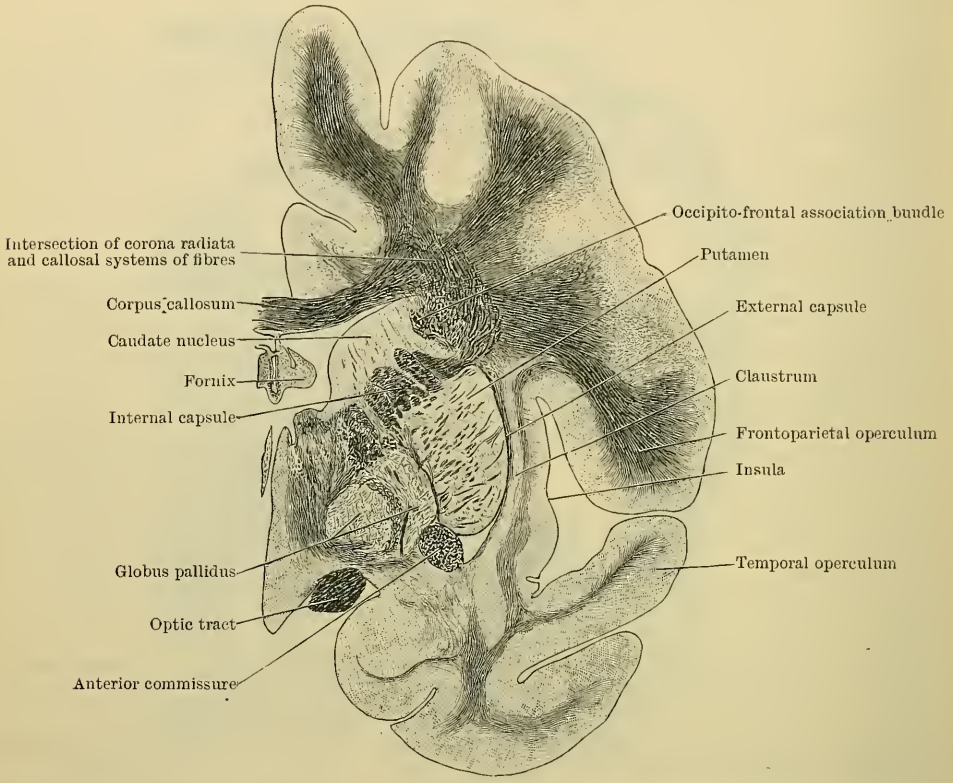


Fig. 468.—Coronal Section through the Left Side of the Cerebrum of an Orang (Weigert-Pal specimen).

The section passes through the middle of the lenticular nucleus.

thickens considerably, and at the base of the brain it comes to the surface at the anterior perforated spot and becomes continuous with the gray matter of the cortex. Its extent corresponds very closely with the area occupied by the insula, and its surface towards this portion of the cerebral cortex shows ridges and depressions corresponding to the insular gyri and sulci.

Amygdaloid Nucleus.—In the forepart of the temporal lobe, in front of, and to some extent above the extremity of the descending horn of the lateral ventricle, there is a round mass of gray matter, called the amygdaloid nucleus. The tail of the caudate nucleus joins its lower part, whilst above it is carried up into the putamen. In front it is continuous with the gray cortex of the cerebrum.

Tænia Semicircularis.—This is a band of fibres which, for the most part, arise in the amygdaloid nucleus. From this it runs backwards in the roof of the descending horn of the lateral ventricle, and then arches upwards and forwards, so as to gain the floor of the body of the lateral ventricle. In both situations it lies close to the inner side of the nucleus caudatus, and finally, at the foramen of Monro, it bends downwards towards the anterior commissure. Some of its fibres pass in front and others behind the commissure, and ultimately they end in the locus perforatus anticus (Kölliker).

Internal Capsule.—This term is applied to the broad band of white matter which intervenes between the lenticular nucleus, on the outside, and the optic

thalamus, tænia semicircularis, and caudate nucleus on the inner side. It presents many different appearances, according to the plane in which the brain is cut. In the region of the mesencephalon, a coronal section through the brain shows that in great part the internal capsule is directly continuous with the crusta of the crus cerebri (Fig. 440, p. 547). In horizontal section the internal capsule is observed to be bent upon itself opposite the tænia semicircularis, or the interval between the caudate nucleus and the thalamus. This bend, which points inwards, is called the **genu**. About one-third of the internal capsule lies in front of the genu, and is termed the anterior limb; the remaining two-thirds, which lie behind the genu, constitute the posterior limb.

The **anterior limb of the internal capsule** intervenes between the lenticular nucleus and the caudate nucleus. In its lower and forepart it is much broken up by the connecting bands of gray matter which pass between the forepart of the putamen and the lenticular nucleus.

The anterior limb of the internal capsule is largely composed of corticipetal fibres belonging to the thalamic radiation. It likewise contains corticifugal fibres. The *corticipetal fibres* are of two kinds, viz. thalamo-frontal and thalamo-striate. The former, which arise in the optic thalamus, go through the anterior limb of the internal capsule to reach the cortex of the frontal lobe. The thalamo-striate fibres likewise arise in the thalamus and enter the anterior limb, to reach the caudate and lenticular nuclei.

The corticifugal fibres are represented by the fronto-thalamic, the strio-thalamic, and the fronto-pontine tracts.

The **fronto-pontine tract** arises in the cortex of the prefrontal region, traverses the anterior limb of the internal capsule, forms the inner fifth of the crusta of the crus cerebri, and finally ends in the nucleus pontis.

The **posterior limb of the internal capsule** is placed between the optic thalamus and the lenticular nucleus, and it extends backwards for a short distance beyond the hinder end of the putamen on the outer side of the posterior part of the thalamus and of the tail of the caudate nucleus. The posterior limb, therefore, is spoken of as consisting of a lenticular and a retrolenticular part.

The **lenticular part** of the posterior limb is composed of both corticipetal and corticifugal fibres. The *corticipetal fibres* enter the internal capsule from the outer aspect of the optic thalamus, and are composed of fibres which arise within the thalamus, and proceed upwards to the cerebral cortex.

The *corticifugal fibres* consist of the pyramidal tract and the cortico-thalamic fibres.

The great **motor** or **pyramidal tract**, descending from the Rolandic area of the cortex, occupies the anterior half of the lenticular part of the internal capsule. The fibres, which go to the nucleus of the facial nerve, lie close to the genu, and behind these are the fibres which go to the hypoglossal nucleus; still further back are pyramidal fibres which enter the spinal cord and end around the motor cells of the anterior horn of gray matter. This pyramidal tract has been observed occupying the middle part of the crusta of the crus cerebri, into which it passes directly from the internal capsule.

The **retrolenticular part** of the posterior limb contains: (1) the fibres of the optic radiation as they pass to establish their connexions with the thalamus, superior quadrigeminal body, and corpus geniculatum externum; (2) the fibres of the auditory radiation, or those which connect the auditory cortical field in the temporal lobe with the corpus geniculatum internum (Figs. 418, p. 520, and Fig. 439, p. 546); (3) the temporo-pontine tract, which is composed of fibres which take origin in the two upper convolutions of the temporal lobe and pass through this section of the internal capsule to reach the outer part of the crusta of the crus cerebri. Through this they reach the ventral part of the pons, in the gray matter of which they end.

When the fibres of the internal capsule are traced upwards they are found to spread out widely from each other in a radiating or fan-shaped manner, so as to reach the various convolutions of the cerebral hemisphere. This arrangement is termed the **corona radiata**. The callosal system of fibres, as they proceed into the hemisphere, also radiate, and they intersect the fibres of the corona radiata (Fig. 468, p. 582).

External Capsule.—The thin lamina of white matter between the outer aspect of the putamen and the claustrum is called the external capsule. This joins with

the internal capsule in front of and behind the putamen, and in this manner the lenticular nucleus is encapsulated by white matter.

Morphological Subdivision of the Cerebral Hemisphere.—In many respects the descriptive anatomy of the human cerebral hemisphere is not in accord with the facts which have been acquired regarding its morphological evolution; and of recent years this discrepancy has become more marked through the important researches of Elliot Smith.

From the morphological point of view the cerebral hemisphere may be regarded as being composed of three parts, viz. the rhinencephalon, the corpus striatum, and the neo-pallium.

The **rhinencephalon** is the most archaic part of the hemisphere, and in the brains of the lower vertebrates (fishes, amphibians, reptiles) it constitutes its chief bulk. In the human brain it is represented by the olfactory bulb, olfactory tract and its roots, the anterior perforated space, the uncus, the gyrus subcallosus, the septum lucidum, the hippocampus, fornix, gyrus dentatus, and the gyrus supracallosus.

The uncus, with the aborted lateral stria of the olfactory peduncle, is all that remains in the human brain of the relatively huge pyriform lobe of many of the lower mammals. The hippocampal convolution which lies to the outer side of the dentate fissure, although it runs continuously into the uncus, is not a part of the rhinencephalon. It belongs to the neo-pallium. The feeble furrow, termed the incisura temporalis which separates the uncus from the temporal pole, is one of the most primitive of the cerebral fissures. It represents the rhinal or ecto-rhinal fissure—the bounding fissure of the rhinencephalon.

The **neo-pallium** is represented by the rest of the hemisphere, exclusive of the corpus striatum. It therefore comprises almost the whole of the convoluted cortex on the surface together with its associated white matter. The great development of the neo-pallium in man is one of the most distinctive characters of the human brain.

In their phylogenetic evolution the rhinencephalon and the neo-pallium appear to develop more or less independently of each other. In certain cases the former atrophies, whilst the neo-pallium attains a high degree of development (*e.g.* man, monkey, whale, etc.), in others the reverse development occurs (*e.g.* hedgehog and many other mammals), in which the rhinencephalon forms a large part of the hemisphere and the neo-pallium is relatively small.

Intimate Structure of the Cerebral Hemisphere.

The cerebral hemisphere is composed of an external coating of gray matter, termed the **cortex**, spread over an internal mass of white matter, which is called the **medullary centre.** The cortex is of peculiar interest, seeing that there is good reason for believing that in it the higher functions of the brain, or those which may be classed under the general designation of the intellectual functions, take place. It is within the same layer of gray matter that the influence of those external impressions, which gain access to the cerebro-spinal axis through the senses, finally take shape as consciousness; and in it also are placed the centres which carry on the psycho-motor functions. The white medullary centre is composed of nerve-fibres which constitute the paths along which the influence of impressions is carried to and from the cortex, and from one part of the cortex to another.

The Cerebral Cortex.

The gray cortex is spread over the entire surface of the cerebral hemisphere, but it does not form a layer of equal thickness in all localities. At the summit of a convolution it is always thicker than at the bottom of a furrow. The maximum thickness of cortex (about 6 mm.) is attained in the upper parts of the two central convolutions, whilst the minimum (about 2·5 mm.) may be observed in the region of the occipital pole. The amount of gray cortex differs considerably in different individuals, and appreciably diminishes in old age. It is also stated, but upon imperfect evidence, that it is relatively more abundant in the male than in the female.

In structure, likewise, marked differences may be noted in the gray cortex of different regions, and excellent work has been recently done in the direction of connecting these structural peculiarities with the functional characteristics of particular areas and applying them to the determination of morphological problems connected with the cerebral surface (Campbell and Bolton). In certain localities this structural difference is quite apparent to the naked eye when sections are made through the cortex. There are, however, no sharp transitions in structure. One form of cortex passes, as a rule gradually and almost insensibly, into the variety of cortex which is distinctive of an adjoining region, and throughout the whole

mass a general ground type may be recognised. It is only to those general structural features which more or less characterise the entire cortical layer that we shall be able to refer.

When sections are made through the fresh brain, and the cut surface is closely inspected, it will usually be apparent that the cortex is indistinctly stratified. On the outside there is a thin, whitish layer, and beneath this the gray matter presents two strata of very nearly equal thickness, viz. a middle, gray-coloured stratum and an inner, yellowish-red stratum. Between the two latter layers a narrow white band is, in many places, visible. This is termed the **outer band of Baillarger**. When the layers indicated above are present, four strata superimposed on each other are recognised; but in certain regions, as, for instance, in the anterior central convolution, a second white streak traverses the deep or inner gray layer and divides it into two. This is termed the **inner white band of Baillarger**, and, when it is present, the gray cortex becomes divided obscurely into six alternating white and gray layers.

The outer band of Baillarger is strongly marked in the region of the calcarine fissure and gives a characteristic appearance to this portion of the cortex. In this locality it receives the name of the **band of Vicq d'Azyr** or the **stria of Gennari** (Fig. 465, p. 579).

According to Henschen the visual centre is strictly limited to the region in which the stria of Gennari is present. Elliot Smith applies the name of "striated area" to this cortical district, and considers that it affords a means of identifying homologous sulci in the brains of man and the apes.

To obtain a full understanding of the minute structure of the cerebral cortex many different methods must be employed, and it is only by combining the several separate pictures which are thus afforded that the end in view is, in some measure, reached.

The stratification indicated above has little bearing upon the more essential points of the intimate structure of the cortex. The three white layers are brought about by aggregations of fibres running in a tangential direction, or, in other words, in a direction parallel to the surface of the convolution.

Nerve-cells.—According to the arrangement and the characters presented by the nerve-cells which are met with at different depths, it is now usual to recognise four layers in the cortex. These are: (1) the stratum zonale; (2) the layer of small pyramidal cells; (3) the layer of large pyramidal cells; and (4) the layer of polymorphic cells.

As the pyramidal cells are specially characteristic of the cerebral cortex, we shall, in the first instance, describe the two layers which contain them. The difference between these two layers largely depends upon the difference in the size of the constituent cells. Taken together, the second and third layers constitute the chief part of the cortex; they merge insensibly into each other, and, in the parietal and frontal lobes, the layer of large pyramidal cells is the thickest of all the layers. In both of these strata the pyramidal cells present the same form, and apparently also similar connexions.

A **pyramidal cell** has a triangular outline. Its apex is directed towards the surface of the convolution and is drawn out into a long, tapering, apical, dendritic process; its base is turned towards the medullary centre of the gyrus, and from this (usually from the centre) a slender axon proceeds. Numerous lateral dendrites are given off from both sides of the cell-body, and particularly from the two basal corners. The apical dendrite varies in length, according to the depth at which the cell is placed in the cortex. In every case it passes straight towards the surface of the convolution. Every here and there fine lateral branches come off from it, and ultimately it enters the stratum zonale, where, close to the surface, it ends by breaking up into a large number of fine terminal filaments, which spread out horizontally in every direction and interlace closely with the corresponding filaments of other pyramidal cells and with the other elements of this layer.

The axon of the cell descends, gives off collaterals, assumes a medullary sheath, and enters the central white core of the gyrus as a nerve fibre.

The **stratum zonale** is chiefly composed of fibres which run in a tangential direction, or, in other words, parallel to the surface. These form an interlacement of considerable density and extreme complexity. The elements which for the most part enter into the formation of this feltwork are: (1) the terminal filaments of the apical dendrites of the pyramidal cells; (2) the terminal filaments of certain corticipetal fibres, which enter the cortex from the white centre of the gyrus; (3) the axons of certain small cells peculiar to this stratum; (4) the axons of the cells of Martinotti. Spread over the surface of this tangential interlacement of fibres, which constitutes the most important part of the stratum zonale, there

is a thin layer of neuroglia which intervenes between it and the pia mater, which covers the convolution. The stratum zonale is not devoid of nerve-cells, although these are small and somewhat indefinite in their connexions. The most characteristic form is a small fusiform cell described by Cajal, which sends out from either end a long process and which lies in the deeper part of the layer. The long filamentous processes of this cell thread their way between the other fibres in a tangential direction and give off minute branches which pass towards the surface.

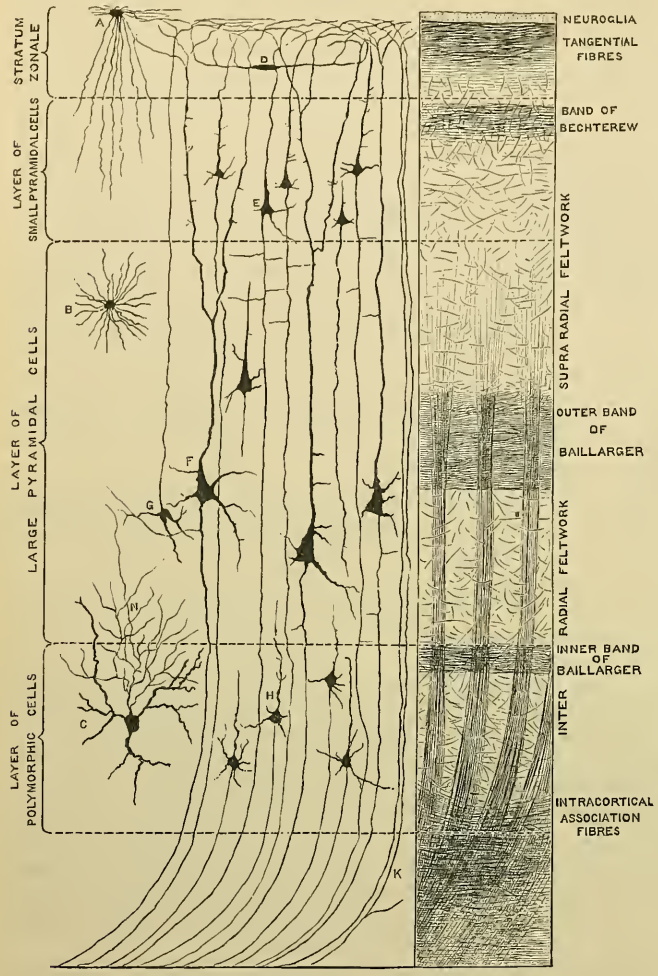


FIG. 469.—DIAGRAM TO ILLUSTRATE MINUTE STRUCTURE OF THE CEREBRAL CORTEX.

A. } Neuroglia cells.
B. }
C. Cell with short axon (N) which breaks up in a free arborisation.
D. Spindle-shaped cell in stratum zonale.
E. Small pyramidal cell.
F. Large pyramidal cell.
G. Cell of Martinotti.
H. Polymorphic cell.
K. Corticipetal fibres.

The **deepest layer of the cortex** contains the polymorphic cells. These cells are not large, and they present many different forms. Numerous dendrites proceed from the cells of this group, but none of these reach the stratum zonale, and in this respect the polymorphic cells offer a marked contrast to the pyramidal cells. The axons of the polymorphic cells, however, like those of the pyramidal cells, enter the white centre of the gyrus in the shape of nerve-fibres.

In addition to the cells characteristic of the several layers, there are two which may be found amongst the pyramidal or amongst the polymorphic cells. These are: (1) the cells of Golgi; (2) the cells of Martinotti.

A **cell of Golgi** has this peculiarity—that its axon, close to its origin, begins to divide, and very soon loses its individuality by breaking up into a perfect maze of branches, none of which pass far from the neighbourhood of the cell-body and none of which enter the stratum zonale.

The **cell of Martinotti** is small and is chiefly found in the deeper part of the cortex. Its leading peculiarity is, that its slender axon runs in a contrary direction to the axons of the pyramidal cells and of the polymorphic cells. In other words, it proceeds towards the surface, and, entering into the stratum zonale, divides into terminal filaments, which spread out in the tangential interlacement characteristic of this layer.

Nerve-Fibres.—The arrangement of the nerve-fibres can best be studied in vertical sections through the gray cortex, which have been specially treated with this end in view. In such preparations bundles of nerve-fibres are seen to radiate into the gray cortex from the surface of the white centre of the gyrus. As these proceed through the polymorphic layer into the layer of large pyramidal cells, they gradually become less distinct, and, finally, they disperse and are lost to view before they reach the layer of small pyramidal cells. In the intervals between the radiating bundles the polymorphic and large pyramidal cells are arranged in columns, and in the same intervals an open

feltwork of intercrossing fibres is evident. After the radiating fibre-bundles have disappeared the same feltwork of fibres is visible in the gray matter, and consequently it is convenient to distinguish, with Edinger, an **inter-radial feltwork** and a **supra-radial feltwork** of fibres in the cortex. The fibres which enter into the composition of the different radial bundles vary in number from ten to twenty, and they gradually diminish in number as they proceed onwards. This diminution is due to their joining the various cells that they meet (both polymorphic and pyramidal) as their axons. The fibres in a given bundle also vary much in size, and it may be noticed that the largest fibres disappear in the vicinity of the large pyramidal cells, which shows clearly that it is with these that they are connected. But, in addition to cell-axons, the radial bundles contain fibres of an altogether different type, viz. corticipetal fibres, which pass through all the layers of the cortex and end in fine terminal filaments in the tangential interlacement of the stratum zonale.

The inter-radial and supra-radial feltwork is largely formed of the collaterals which issue from the axons. By a condensation of this feltwork the two bands of Baillarger are formed. The outer band, which is the broader and better marked, occurs in the deeper part of the layer of the large pyramidal cells. The inner band, when present, is formed in the superficial part of the layer of polymorphic cells.

Another condensation of the fibre-feltwork in the superficial part of the supra-radial region may be noted in certain localities. This is termed the **band of Bechterew**.

It has been noted that up to a certain point the tangential fibres increase in quantity as age advances, and there is reason to believe that upon the richness with which the gray cortex is supplied with fibres—more especially of the tangential variety—depends to some extent the intellectual capacity of an individual.

Whilst the general mass of the cortex for the most part conforms more or less closely to the ground-type described above, showing merely deviations characteristic of the different regions, there is one part of the cortex, viz. the cornu ammonis and the fascia dentata, in which the structural arrangement of the elements is very markedly different. To some extent this is due to the complicated manner in which, in this region, the cortex is folded upon itself.

Olfactory Tract and Bulb.

The olfactory tract and bulb arise as a hollow outgrowth from the primitive cerebral vesicle. In many animals with a well-developed olfactory apparatus, the tract and bulb remain hollow; but in man the central cavity becomes obliterated, although traces of the original hollow persist in the shape of ependymal remains, visible in the centre of both tract and bulb. Outside these ependymal elements is a coating of white matter, upon which is laid the gray matter. The gray matter, however, is by no means uniformly distributed over the surface. In the tract, except along the dorsal edge, it is so thinly spread that it is hardly appreciable. In the bulb, on the other hand, there is very little gray matter on the dorsum, but a considerable quantity on the ventral surface; and it is into this that the delicate nerves which enter the cranium through the cribriform plate of the ethmoid bone sink. A brief description of the structure of this infrabulbar mass of gray matter, as well as of the connexions established by its elements, now becomes necessary.

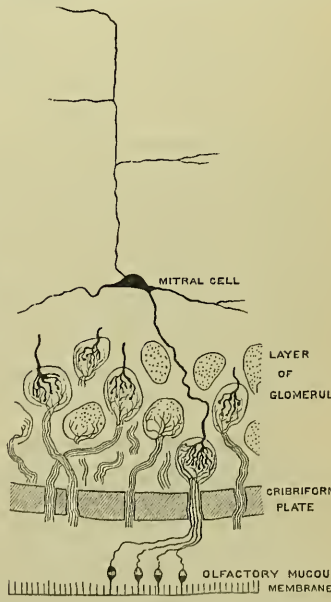


Fig. 470.—Diagram of the Minute Structure of the Olfactory Bulb.

The fibres of the delicate olfactory nerves are to be regarded as the axons of the olfactory cells of the olfactory mucous membrane. They enter the ventral surface of the olfactory bulb, and there each breaks up in an arborescent fashion into a tuft of terminal filaments. A thick dendrite from a mitral cell of the bulb passes down towards this terminal tuft, and, coming into contact with it, breaks up and terminates in a similar manner. In this way a large number of globular bodies, formed by the arborescent terminations of a mitral dendrite and of certain olfactory nerve-fibres, are formed. These are the **olfactory glomeruli** of the bulb. The mitral cells lie deeper in the olfactory bulb. Each gives

off several dendrites and one axon. Only one dendrite enters into the formation of a glomerulus, but several nerve-fibres may be connected with such a body. It thus happens that, through its dendrite, a mitral cell may stand in connexion with several olfactory nerve-fibres. The axon of the mitral cell passes upwards to the white matter of the bulb, enters this, and is conducted through the tract towards the cerebral cortex.

White Medullary Centre of the Cerebral Hemisphere.

The white matter of the hemisphere which lies subjacent to the gray cortex is composed of medullated nerve-fibres, arranged in a very intricate manner. According to the connexions which they establish these fibres may be classified into three distinct groups, viz. (1) commissural fibres; (2) association fibres; and (3) projection fibres.

Commissural Fibres.—These are fibres which link together portions of the gray cortex of opposite cerebral hemispheres. They are arranged in three groups forming three definite structures, viz. the corpus callosum, the anterior commissure, and the psalterium or the hippocampal commissure.

The **corpus callosum** has in a great measure been already studied (p. 570). As it enters each hemisphere, its fibres spread out in an extensive radiation (the radiation of the corpus callosum). It thus comes about that every part of the cerebral cortex, with the exception of the bulbus olfactorii and the under and fore part of the temporal lobe, is reached by the callosal fibres. But it should be clearly understood that all the regions of the cortex do not receive an equal proportion of fibres; in other words, some cortical areas would appear to be more plentifully supplied than others. Another point of some importance consists in the fact that the callosal fibres do not, as a rule, connect together symmetrical portions of the gray cortex. As the fibres cross the mesial plane they become greatly scattered, so that most dissimilar parts of the cortex of opposite hemispheres come to be associated with each other.

Each callosal fibre arises in one hemisphere and ends by fine terminal arborisations in the cortex of the opposite hemisphere. It may arise in any one of three ways, viz. (1) as the axon of one of the cortical cells, either pyramidal or polymorphic; (2) as the collateral of a fibre of association; (3) as the collateral of a fibre of projection.

Many cases have been recorded in which, through congenital defect, the corpus callosum has not been developed. In the description of this structure on p. 570 attention has been called to a layer of callosal fibres which sweep over the posterior and descending horns of the lateral ventricle, so as to form the immediate outer wall of the cavity. This layer is called the **tapetum**, and it has been stated that when the corpus callosum is absent the tapetum is found in a well-developed condition. Further, it has been asserted that in cases where the corpus callosum has been experimentally destroyed the tapetum suffered no degeneration (Muratoff). Certain anatomists are, therefore, inclined to argue that the tapetum has little or no connexion with the corpus callosum. This assertion, however, cannot by any means be regarded as being proved. There is a large amount of evidence on the other side. Thus, Mingazzini has seen a case of failure of the corpus callosum which was accompanied by a corresponding defect in the tapetum, whilst softening of the splenium and the forceps major has been observed by Anton to be accompanied by a secondary degeneration of the tapetum. Further, the recent experimental evidence of Ferrier and Turner would appear to support the older view that the tapetum is associated in the closest manner with the corpus callosum.

The **anterior commissure** (commissura anterior) is a structure supplemental to the corpus callosum. It connects together the two olfactory lobes, and also portions of opposite temporal lobes. It presents a cord-like appearance and is arranged in the form of a horse-shoe, the concavity of which looks backwards. The middle free portion is placed immediately in front of the anterior pillars of the fornix as they curve downwards, and also in intimate relation to the anterior end of the third ventricle. Posteriorly, the small portion of the anterior commissure which appears in the ventricle between the two pillars of the fornix is clothed with the ventricular ependyma; anteriorly, the commissure is connected with the lamina cinerea as it stretches from the optic chiasma upwards towards the rostrum of the corpus callosum.

The lateral part of the anterior commissure penetrates the cerebral hemisphere, and, gaining the lower part of the anterior end of the internal capsule, divides into two portions, viz. a small lower olfactory part and a much larger temporal part.

The **olfactory portion** of the anterior commissure is an exceedingly small fasciculus. It passes downwards and forwards, and finally enters the olfactory tract. It is composed (1) of true commissural fibres, which bind one olfactory bulb to the other; and (2) of other fibres, which connect the olfactory bulb of one side with the temporal lobe of the other side.

The **temporal portion** is formed of almost the whole of the fibres of the commissure. It is carried transversely outwards, under the lenticular nucleus, until it gains the interval between the globus pallidus and the putamen. At this point it

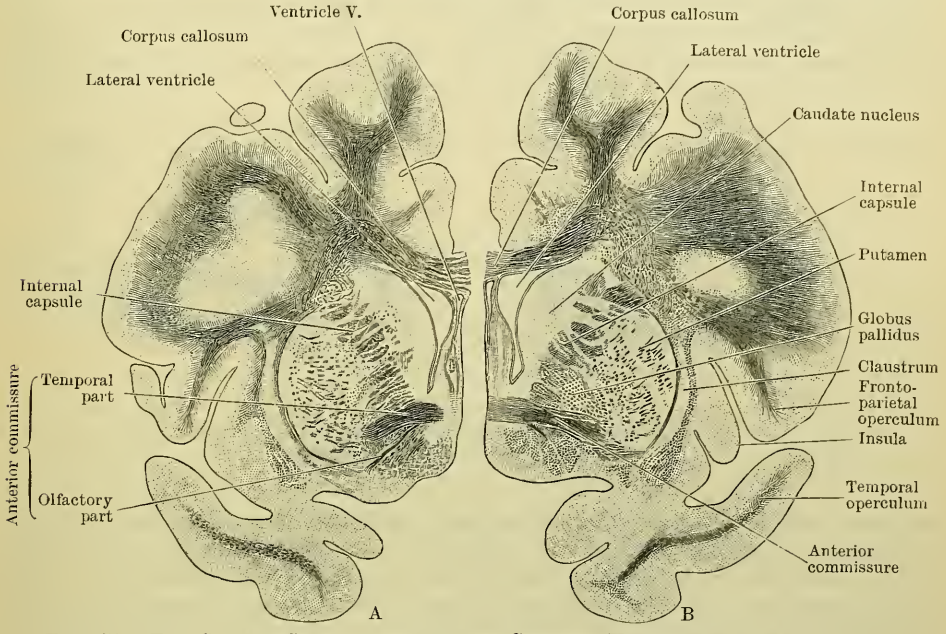


FIG. 471.—TWO CORONAL SECTIONS THROUGH THE CEREBRAL HEMISPHERES OF AN ORANG, IN THE PLANE OF THE ANTERIOR COMMISSURE.

A, Section through the left hemisphere in a plane a short distance behind B, which is a section through the right hemisphere.

changes its direction and sweeps backwards. In coronal sections through the brain, behind this bend, the temporal portion of the anterior commissure appears as an oval bundle of fibres cut transversely and placed in close contact with the under surface of the lenticular nucleus (Fig. 468, p. 582). Finally, it turns sharply downwards on the outer aspect of the amygdaloid nucleus, and its fibres are lost in the white medullary centre of the temporal lobe. The precise part of the cerebral cortex with which these fibres stand in connexion is not known. When the lateral part of the anterior commissure is displayed by dissection, it is seen to be twisted like a rope.

The **psalterium**, or the **hippocampal commissure**, is composed of fibres which connect the cornu ammonis of one side with the corresponding structure of the opposite side. It is described on p. 572.

Association Fibres.—The association fibres bind together different portions of the cortex of the same hemisphere. They are grouped into long and short association bundles.

The greater number of the **short association fibres** pass between adjacent convolutions. They curve round the bottom of the sulci in U-shaped loops. Some of these occupy the deepest part of the gray cortex itself, and are termed *intracortical association fibres* (Fig. 469, p. 586); others lie immediately subjacent to the gray matter—between it and the general mass of the white matter—and receive the name of *subcortical fibres*. Many groups of short association fibres, instead of linking together contiguous convolutions, pass between gyri more or less remote. It is only

after birth, when intellectual effort and education have stimulated different portions of the cortex to act in harmony and in conjunction with each other, that these association fibres assume their sheaths of medulla and become functional.

The **long association fibres** are arranged in bundles which run for considerable distances within the white medullary centre of the cerebral hemisphere, and unite districts of gray cortex which may be far removed from each other. The better known of these fasciculi are the following: (1) the uncinate; (2) the cingulum; (3) the superior longitudinal; (4) the inferior longitudinal; (5) the occipito-frontal.

The **fasciculus uncinatus** is composed of fibres which arch over the stem of the Sylvian fissure and connect the frontal pole, and the orbital convolutions of the frontal lobe, with the front portion of the temporal lobe.

The **cingulum** is a very well-marked and distinct band, which is closely associated with the limbic lobe. Beginning in front, in the region of the anterior perforated spot, it arches round the genu of the corpus callosum and is carried backwards on the upper surface of this structure at the place where its fibres pass into the

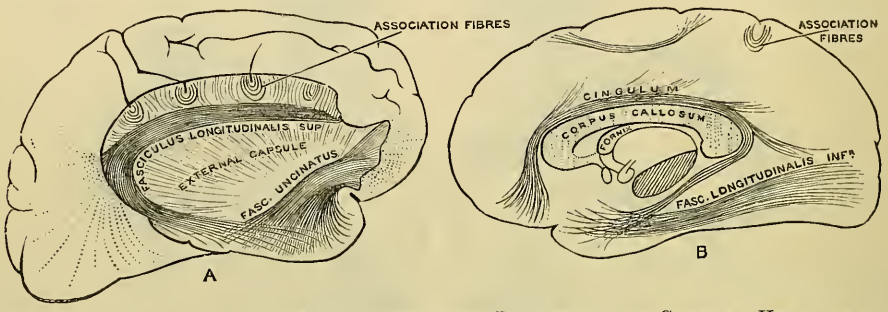


FIG. 472.—DIAGRAM OF THE LEADING ASSOCIATION BUNDLES OF THE CEREBRAL HEMISPHERE. (Founded on the drawings of Déjerine.)

A. Outer aspect of hemisphere. B. Inner aspect of hemisphere.

callosal radiation. The cingulum, therefore, lies under cover of the callosal gyrus and stands in intimate relation to the white centre of this convolution (Fig. 457, p. 570). At the hinder end of the corpus callosum the cingulum turns round the splenium and is carried forwards, in relation to the hippocampal gyrus, to the uncus and the temporal pole. The cingulum is composed of several systems of fibres which only run for short distances within it.

The **fasciculus longitudinalis superior** is an arcuate bundle which is placed on the outer aspect of the foot or basal part of the corona radiata and connects the frontal, occipital, and temporal regions of the hemisphere. It lies in the base of the fronto-parietal operculum and sweeps backwards over the insular region to the posterior end of the Sylvian fissure. Here it bends downwards round the hinder end of the putamen and proceeds forwards in the temporal lobe, to reach its anterior extremity. As it turns downwards to reach the temporal lobe numerous fibres radiate from it into the occipital lobe.

The **fasciculus longitudinalis inferior** is a very conspicuous bundle which extends along the whole length of the occipital and temporal lobes (Fig. 457, p. 570). In the occipital lobe it is placed on the outer aspect of the optic radiation, which takes a similar direction and from which it is distinguished by the greater coarseness of its fibres (Figs. 462, p. 576; 465, p. 578; 473, p. 592). It is not present in the macaque monkey (Ferrier and Turner), but is well developed in the orang and the chimpanzee,

The **fasciculus occipito-frontalis** is a bundle of fibres which runs in a sagittal direction in intimate relation to the lateral ventricle (Fig. 468, p. 582). It has been pointed out (Forel, Onufrowicz, and others) that, in cases where the corpus callosum fails to develop, the tapetum remains apparently unaffected, and Déjerine has endeavoured to prove that the fibres of this layer really belong to the fasciculus occipito-frontalis. According to Déjerine, the fasciculus occipito-frontalis lies on the inner aspect of the corona radiata in intimate relation to the caudate nucleus, and posteriorly it spreads out over the upper and outer aspect of the lateral ventricle, immediately outside the ependyma, where it constitutes the tapetum (see p. 588). There is a considerable amount of literature

dealing with this subject, and the most probable explanation of the difficulty would appear to be that the tapetum is composed of fibres derived from both the corpus callosum and the fasciculus occipito-frontalis of Déjerine.

Projection Fibres.—The projection fibres are those which connect the cerebral cortex with nuclear masses placed at a lower level. The great bulk of these fibres are found in the corona radiata. This has already been seen to be formed by the continuation upwards of the internal capsule (p. 583). In the corona radiata the fibres which, lower down, are gathered together in the compact mass which constitutes the internal capsule, radiate in every direction, intersect the radiation of the corpus callosum, and finally reach every region of the cortex. Although the fibres of the corona radiata represent the chief bulk of the projection fibres, it should also be borne in mind that a certain number gain the cortex by a different route, notably through and under the lenticular nucleus and by the path offered by the external capsule.

The projection fibres of the cerebral hemisphere may be classified into (1) corticipetal, and (2) corticifugal groups; and under these headings the following great strands may be arranged:—

Corticipetal Projection Strands.

1. Thalamo-cortical.
2. Corticipetal fibres of the optic radiation.
3. The auditory radiation.

Corticifugal Projection Strands.

1. The pyramidal or great motor tract.
2. The cortico-thalamic.
3. The fronto-pontine strand.
4. The temporo-pontine strand.
5. The corticifugal fibres of the optic radiation.

The **great motor** or **pyramidal tract** is composed of fibres which arise from pyramidal cells in that portion of the cortex which is spread over the Rolandic area, or, in other words, in the district immediately in front of the fissure of Rolando. The fibres descend through the corona radiata into the posterior limb of the internal capsule. From this point the further course of the pyramidal tract has been traced, viz. through the central part of the crusta of the crus cerebri, the ventral part of the pons, and the pyramid of the medulla oblongata. At the level of the foramen magnum it decussates in the manner already described, and enters the spinal cord as the crossed and direct pyramidal tracts. The fibres composing these end in connexion with the ventral or motor column of cells, from which the fibres of the anterior roots of the spinal nerves arise.

The **fronto-pontine strand** is composed of fibres which arise as the axons of the cells in the cortex which covers the portion of the frontal lobe, which lies in front of the præcentral furrows. It descends in the anterior limb of the internal capsule, enters the mesial part of the crusta of the crus cerebri, through which it gains the ventral part of the pons. In this its fibres end, by forming arborisations around the cells of the nucleus pontis.

The **temporo-pontine tract** consists of fibres which spring from the cells of that part of the cortex which covers the middle portions of the two upper temporal convolutions. It probably represents a corticifugal tract belonging to the auditory system, seeing that it springs to some extent from the auditory cortical area. The temporo-pontine tract passes inwards under the nucleus lenticularis, enters the retrolenticular part of the hinder limb of the internal capsule, and thus gains the outer part of the crusta of the crus cerebri. From this it descends into the ventral part of the pons, in which it ends in the nucleus pontis (Fig. 439, p. 546).

The **optic radiation** forms a very definite and easily demonstrated tract of longitudinally-directed fibres in the white medullary centre of the occipital lobe. It lies on the outer side of the ventricular cavity, from which it is separated by the fibres of the tapetum and the ependyma of the ventricle (Figs. 462, p. 576; and 465, p. 579). To the outer side of, and applied closely to, the optic radiation is another longitudinal tract of fibres in this part of the medullary centre of the cerebral hemisphere, viz. the inferior longitudinal association bundle; but the fibres of the latter fasciculus are coarser and are stained more deeply by the Pal-Weigert method, and thus they can, as a rule, be easily distinguished from the optic radiation. Traced

in a backward direction, the fibres of the optic radiation disperse and pass to the cortex of the occipital lobe on both its mesial and outer aspects. This is a matter of interest, seeing that the visual centre is placed in this cortical district, and more particularly on the mesial aspect in the immediate neighbourhood of the calcarine fissure (Flechsig and Henschen). When the optic radiation is followed in a forward direction it is seen to enter the retrolenticular part of the posterior limb of the internal capsule, from whence its fibres pass to the pulvinar of the optic thalamus, to the corpus geniculatum externum and the superior quadrigeminal body.

As we have noted, the optic radiation is composed partly of corticifugal and partly of corticipetal fibres (p. 552). The former arise from cells in the occipital cortex and end in the pulvinar and the superior quadrigeminal body; the corticipetal fibres arise in the pulvinar and in the corpus geniculatum externum and end in the occipital cortex (Ferrier and Turner).

The system of fibres which belong to the **mesial fillet** and the **superior cerebellar**

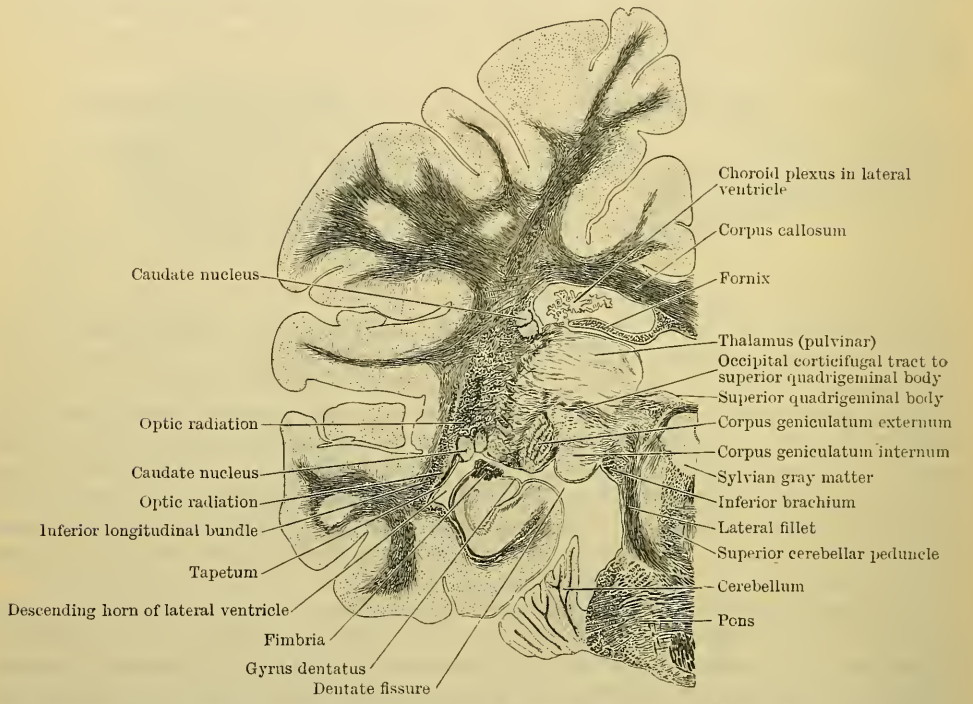


FIG. 473. — CORONAL SECTION THROUGH THE LEFT SIDE OF THE CEREBRUM, MESENCEPHALON, AND PONS, IN THE REGION OF THE PULVINAR OF THE THALAMUS, AND THE CORPORA GENICULATA (Chimpanzee; Weigert-Pal specimen).

peduncle have been already more or less fully dealt with (pp. 535 and 539). The **fillet system** represents the continuation upwards of the posterior columns of the cord. The first nuclear internodes in the system are met with in the medulla in the shape of the cuneate and gracile nuclei. It is here that the fillet first takes definite shape, and, as it passes upwards through the tegmental part of the medulla and pons, it receives many additions to its strength in the form of fibres from the nuclei of termination of the afferent cranial nerves. Finally, passing through the tegmentum of the mesencephalon, it reaches the subthalamic region and enters the ventral aspect of the thalamus. This may be looked upon as being the second internode laid across the path of the fillet, and its fibres end in arborisations around the thalamic cells.

The **fibres of the superior cerebellar peduncle** encounter two nuclear internodes as they pass towards the cerebral cortex, viz. the red tegmental nucleus and the optic thalamus (p. 536).

The **fibres of the auditory radiation** arise as the axons of cells situated in the internal geniculate body. They enter the retrolenticular part of the posterior limb of the internal capsule and proceed under the lenticular nucleus towards the

temporal lobe. Here they end in the area of cortex which constitutes the auditory centre. This corresponds to the middle portion of the superior temporal convolution, and also to the rudimentary transverse gyri of Heschl, which are present on the insular surface of the temporal operculum.

The **thalamo-cortical cortico-thalamic systems** include the fibres which constitute a double bond of connexion between the thalamus and all parts of the cortex. They are sufficiently described at p. 545.

The remarkable researches of Flechsig have added greatly to our knowledge of the different tracts of fibres in the cerebral hemisphere. By studying the periods at which these tracts myelinate he has been able to note the manner in which the different areas of the cortex are bound together and also linked on to subjacent centres. He has arrived at a highly important conception regarding the functional value of different districts of the cortex, founded upon their anatomical connexions. He recognises four sense-areas in the cortex, viz. the somæsthetic area, the visual area, the auditory area, and the olfactory area.

The **somæsthetic area** is the field of general sensibility and is the most extensive of all. It includes the two central convolutions, the posterior portions of the three frontal convolutions, the paracentral convolution, and the adjoining part of the callosal convolution.

The **visual area** is placed on the inner aspect of the occipital lobe, and more particularly in the immediate neighbourhood of the calcarine fissure.

The **auditory area** corresponds to the middle third of the superior temporal convolution and to the transverse gyri of Heschl.

The **olfactory area** includes the locus perforatus anticus, the trigonum olfactorium, the anterior part of the callosal convolution, and the uncus.

These sense-areas are peculiarly rich in their supply of projection fibres, and each is provided with an extensive system of both corticifugal and corticipetal fibres. Thus the somæsthetic area

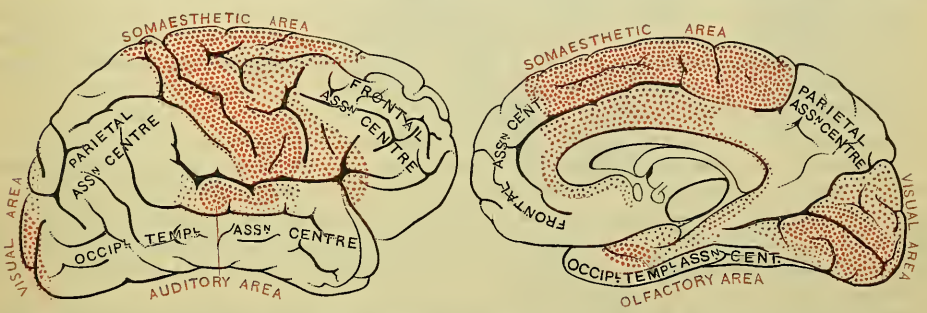


FIG. 474.—DIAGRAMS to show Flechsig's sensory and association areas on the surface of the cerebral hemisphere.

is the field where the motor pyramidal tract takes origin and within which the tracts of general sensibility end. The visual area has the corticipetal and corticifugal fibres of the optic radiation. The auditory area has the corticipetal auditory radiation and also the corticifugal temporo-pontine tract. In man the olfactory area is feebly developed, and Flechsig has not been able to establish, with certainty, its corticipetal and corticifugal projection tracts.

The sense-areas differ greatly from each other in the extent of cerebral surface which they cover. The size in each case is in strict conformity with the peripheral area with which each is in connexion. It can easily be understood, therefore, how the somæsthetic area, representing as it does on the cortex all the parts of the body outside the special organs of sense, from which sensory nerves proceed, should be so large. Further, it is manifest why the visual sensorial area, which in the cortex is the corresponding part to the retina, should be of greater extent than the auditory field, which represents the cochlea, and the olfactory area, which represents a small amount of olfactory mucous membrane in the nasal chamber.

The four sensorial areas, taken together, only form about one-third of the entire cerebral surface. The remaining two-thirds of the cortex constitute what Flechsig has termed the **association centres**. The great extent of these in man must be regarded as a special human characteristic. These centres differ from the sensorial areas in being poorly provided with projection fibres. They have little direct connexion with the centres which lie at a lower level. Indeed, the only direct bond of union over a very large extent of these association areas with lower centres consists of the thalamo-cortical fibres, which pass to them from the thalamus. But, on the other hand, they are rich in association fibres, and are linked in the most complete and perfect manner by these fibres to the sensorial areas.

Flechsig regards these association areas as constituting the portions of cortex in which the higher intellectual activities are carried on, and he further believes that they exercise an important controlling influence over the sense-areas. More particularly is this control exhibited in the case of the great somæsthetic area, within which the influence of all bodily impressions is received and transformed into consciousness, and within which the impulses which are thereby

excited take definite form. These impulses, according to Flechsig, are, in a measure, in all properly-balanced minds, held in subjection by the higher feelings, which assume shape in the association centres.

In his study of the fœtal and infantile brain Flechsig has shown that the fibres of the sensory paths become medullated in the first instance; then the corticifugal fibres which go out from the sense-areas assume their sheaths of myelin; and, further, that it is not until a month after birth, and after the projection fibres in connexion with the sense-areas are myelinated, that the association areas become linked on by medullated association fibres with the sense-areas.

Development of the Parts derived from the Fore-brain.

It has been previously noted that the fore-brain very early shows an obscure subdivision into a front portion, termed the telencephalon, and a hinder part, called the diencephalon, which corresponds more nearly to the original cavity of the fore-brain. The cavity of third ventricle is derived from both, and stretches forwards, therefore, to the lamina terminalis, which in its lower part is represented in the adult by the lamina cinerea.

The lateral wall of both sections of the primitive fore-brain shows a subdivision into a dorsal or alar and a ventral or basal lamina. The groove which indicates this separation is the sulcus of Monro, and is evident even in the adult brain.

In recognising an alar and basal lamina in the fore-brain the teaching of Professor His is followed. This subdivision, however, is not admitted by all observers, and some hold that the fore-brain is to be regarded as a great diverticular expansion which grows out from the mid-dorsal and alar laminæ of the mesencephalon.

Alar Lamina.—The alar part of the lateral wall of the *telencephalon* is pushed out to form the diverticulum, which ultimately constitutes the cerebral hemisphere, and thus from a very early period the primitive position of this part of the lateral wall is indicated by the wide foramen of Monro, or aperture of communication between the cavity of the cerebral hemisphere and the third ventricle.

The alar part of the lateral wall of the *diencephalon* is utilised for the development of the thalamus, the epithalamus, and the metathalamus. Of these the optic thalamus is derived from the anterior and by far the greatest part of the alar wall. It arises as a large oval swelling, which gradually approaches its fellow of the opposite side, and thus diminishes the width of the third ventricle. Finally, the two bodies come into contact in the mesial plane and cohere over an area corresponding to the gray commissure. This occurs about the end of the second month.

From that section of the lateral wall to which the name of metathalamus is given the two geniculate bodies arise. Each of these shows, in the first place, as a depression on the inside, and a slight elevation on the outside, of the wall of the diencephalon. As the thalamus grows backwards, it encroaches greatly upon the territory occupied by the geniculate bodies. It thus comes about that in the adult brain the internal geniculate body seems to hold a position on the lateral aspect of the mesencephalon, whilst the external geniculate body, viewed from the surface, appears to be a part of the thalamus.

From the epithalamic region of the wall of the diencephalon are developed the pineal gland, its peduncle, and the habenular region. These parts are relatively much more evident in the embryonic than in the adult brain. The pineal body is developed as a diverticulum of the posterior part of the roof of the diencephalon. Viewed from the dorsal aspect of the brain-tube, this diverticulum shows in the first instance as a rounded elevation, from either side of which a broad ridge runs forwards. This ridge becomes the tænia thalami, whilst in the region of its junction with the pineal elevation the trigonum habenulæ takes shape. The pineal diverticulum ultimately becomes solid, but a small portion of the original cavity is retained as the recessus pinealis of the third ventricle.

Basal Lamina.—The part of the diencephalon and telencephalon which represents the basal lamina lies below the level of the sulcus of Monro, retains its primitive form, and undergoes only slight change. Consequently, when this region in the adult brain is compared with the corresponding region in the embryonic brain, the resemblance between the two is very striking.

In the fore-brain, therefore, it is the alar lamina which plays the predominant part in the formation of the cerebrum. The value, also, of the basal part of the wall of this portion of the neural tube is still further reduced by the fact that it no longer contains the nuclei of origin of efferent nerves. The highest of these nuclei (the oculo-motor) is placed in the mesencephalon.

The region of the fore-brain which lies below the sulcus of Monro is termed the hypothalamus. The part of this which corresponds to the diencephalon is called the pars mammillaris hypothalami, whilst the part in front, which belongs to the telencephalon, receives the name of pars optica hypothalami.

From the pars mammillaris hypothalami are derived the corpus mammillare and a portion of the tuber cinereum. With the pars optica hypothalami are associated the following parts, viz. the tuber cinereum, with the infundibulum and the cerebral part of the pituitary body, the optic chiasma, the optic recess, and the lamina cinerea.

The corpora mammillaria form, in the first instance, a relatively large downward bulging of the floor of the brain-tube. As development goes on this bulging becomes relatively small, and about the fourth month the single projection becomes divided into the two tubercles.

The infundibulum and posterior or cerebral lobe of the pituitary body are developed as a hollow downward diverticulum of the floor of the telencephalon (p. 549). A portion of the original cavity is retained in the upper part of the infundibulum, and constitutes the infundibular recess in the floor of the third ventricle.

The optic nerve is chiefly formed by the passage of fibres backwards from the retina in the wall of the original optic stalk, whilst the chiasma takes form by the transit of fibres across the middle line in front of the infundibulum and behind the optic recess. To a large extent these fibres are derived from the optic nerve. The optic recess of the third ventricle marks the spot where the hollow optic vesicle originally bulged out from the lower and lateral part of the fore-brain, and in the adult it therefore represents a portion of the primitive cavity of the tubular stalk of the optic vesicle. In the course of development the optic nerve fibres, which appear in the stalk of the optic vesicle to form the optic nerve, seek an attachment much further back, and through the optic tract they are even carried as far as the mesencephalon.

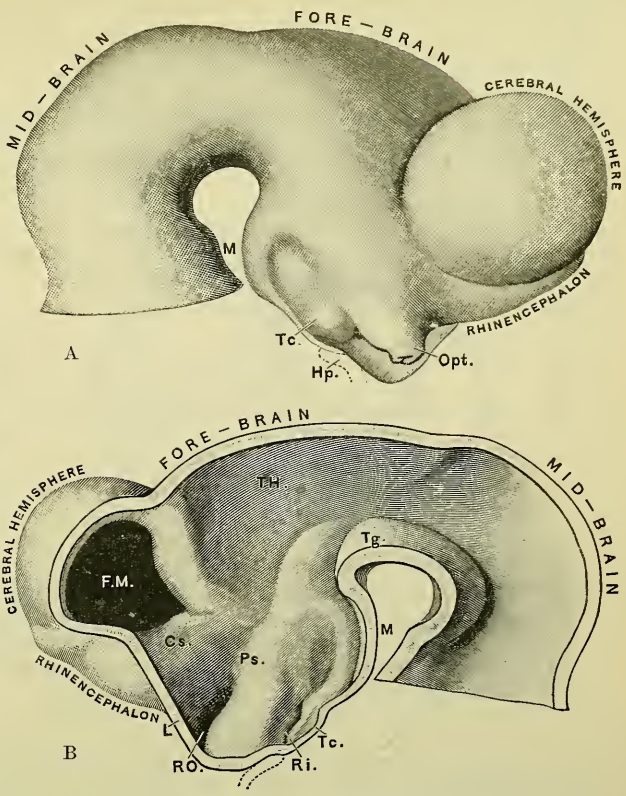


FIG. 475.—TWO DRAWINGS OF THE EMBRYONIC BRAIN (by His).

A, Reconstruction of the fore-brain and mid-brain of His's embryo KO; profile view. B, Same brain as A, divided along the mesial plane and viewed upon its inner aspect.

M, Mammillary eminence; T.c, Tuber cinereum; Hp, Hypophysis (pituitary diverticulum from buccal cavity); Opt, Optic stalk; TH, Optic thalamus; Tg, Tegmental part of mesencephalon; P.s, Par subthalamica; C.s, Corpus striatum; F.M, Foramen of Monro; L, Lamina terminalis; R.O, Recessus opticus; R.i, Recessus infundibuli.

The **roof of the fore-brain** remains thin, and does not proceed to the development of nervous elements, except in its posterior part. Here it forms the pineal body and the posterior commissure. In front of these structures the roof of the fore-brain is epithelial, and remains so during life. It constitutes the epithelial roof of the third ventricle, and it becomes involuted along the middle line into the cavity by the choroid plexuses of the ventricle. The posterior commissure appears as a transverse thickening at the bottom of a transverse groove which appears in the roof of the early brain-tube behind the pineal diverticulum.

Cerebral Hemisphere.—The cerebral hemisphere is derived from the alar section of the lateral wall of the telencephalon. From this it grows out and soon assumes very large dimensions. At first it grows forwards and upwards, and a distinct fissure, the

early incisura longitudinalis cerebri, appears between the cerebral hemispheres of opposite sides. The separation of the two cerebral vesicles by the longitudinal fissure begins at the end of the first month. This fissure becomes occupied by mesoblastic tissue, which later on forms the falx cerebri. The cerebral hemisphere, in its further growth, is carried progressively backwards over the hinder parts of the developing brain. At the end of the third month it has covered the optic thalamus. A month later it reaches the corpora quadrigemina, and by the seventh month it has not only covered these, but also the entire upper surface of the cerebellum.

At the end of the first month the olfactory lobe grows out as a hollow protrusion from

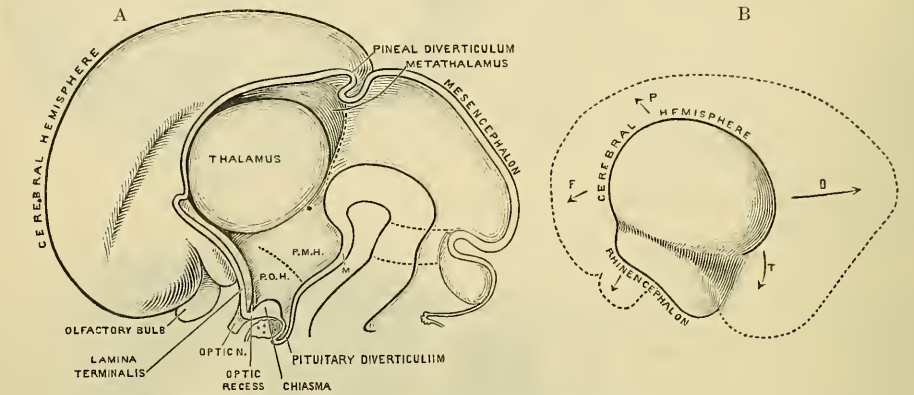


FIG. 476.—TWO DRAWINGS BY HIS, illustrating the development of the human brain.

A, Median section through a fœtal human brain in the third month of development.
B, Schema showing the directions in which the cerebral hemisphere expands during its growth.

P.M.H. Pars mammillaris hypothalami.
P.O.H. Pars optica hypothalami.
M. Mammillary region.
F. Frontal lobe.
P. Parietal lobe.
O. Occipital lobe.
T. Temporal lobe.

the lower and fore part of the cerebral vesicle. This in course of time becomes solid and forms the olfactory tract and bulb. In the adult brain the point which corresponds to the original connexion between the early hollow olfactory diverticulum and the cavity of the cerebral vesicle is represented by the extremity of the anterior cornu of the lateral ventricle.

In the floor of the hollow cerebral hemisphere a thickening takes origin, and this ultimately is developed into the corpus striatum. On the outer surface of the vesicle this thickening is seen to correspond to a depression which constitutes the early Sylvian fossa, the further development of which is described on p. 556.

In the earlier stages of its development the cerebral hemisphere is a thin-walled vesicle with a relatively large cavity, which represents the primitive condition of the lateral ventricle. At first the vesicle is bean-shaped and the cavity is curved. At this stage the outline is very similar to that presented by the cerebral hemisphere of a quadruped, and there is little or no trace of an occipital lobe or of a posterior horn of the lateral ventricle. As development goes on, however, the occipital portion of the hemisphere grows backwards over the cerebellum in the shape of a hollow protrusion, and a distinct occipital lobe enclosing the posterior horn of the lateral ventricle is the result. This developmental stage, which is distinctive of man and the apes, begins about the fourth month.

On the mesial aspect of the cerebral hemisphere, in the early stages of its development, an invagination of the wall of the vesicle takes place into the cavity immediately above and behind the large foramen of Monro. This is the choroidal fissure, and the fold of the cerebral wall, which is thus thrust into the cavity, remains thin and entirely epithelial. After a time mesoblastic tissue from the great longitudinal fissure finds its way into the choroidal fissure and occupies the interval between the two thin layers which form the fold. This mesoblastic tissue forms the choroid plexus of the lateral ventricle, and in the early stages of the hemisphere it is so voluminous that it fills up the relatively large cavity of the lateral ventricle.

Development of the Gyri and Sulci.—In the early stages of its development, the surface of the cerebral hemisphere is smooth and closely applied to the deep surface of the cranial capsule within which it is enclosed.

After the occipital lobe is fully formed and the fifth month is reached, the cranium grows for a time more rapidly than the brain, with the result that a relatively wide space is

left between the cerebral surface and the surrounding cranial envelope. This is occupied by sodden subarachnoid tissue, and when this stage is reached (in the latter part of the fifth month) the sulci and gyri begin to make their appearance. The incomplete sulci owe their origin to the upheaval of the cerebral cortex on either side of the appearing fissures, and the gyri which bound them are formed as the result of an exuberance of surface growth in localised areas. Owing to the wide interval between the cranial wall and the surface of the cerebral hemisphere, the particular surface areas which grow and foreshadow the future gyri suffer no restriction, and they take the form of rounded eminences which rise from the general surface level of the cerebral hemisphere. As growth goes on, however, the brain gradually assumes a bulk more nearly in accord with the cavity of the cranium, and the space for extension becomes more limited. Finally, about the beginning of the eighth month, the gyral elevations come into close contact with the cranial wall, and a stage of growth-antagonism between the brain and its enclosing capsule is entered upon. As a result of this the gyri are pressed together, the fissures assume more definite shape, and the ordinary convolutionary forms make their appearance. So intimate, indeed, is the contact between the cerebral hemisphere and the skull capsule that the gyri, to some extent, produce an imprint on the deep aspect of the cranial bones.

As already explained, the complete fissures are produced by an infolding of the wall of the cerebral vesicle.

Cerebral Commissures.—The development of the cerebral commissures is surrounded with much difficulty. It would seem that the corpus callosum, the anterior commissure, and the fornix all take origin in the lamina terminalis. The triangular interval which is left between these commissures is occupied by the septum lucidum—a structure which has an intimate developmental and morphological connexion with the gyrus subcallosus. The great development of the corpus callosum in man is to be associated with the enormous expansion of the human neo-pallium of which it is the commissure.

Weight of the Brain.

The average weight of the adult male brain may be said to be about 1360 grammes. The female brain weighs rather less, but this is to be expected from the smaller bulk of the female body. Probably the relative weight of the brain in the two sexes is very much the same. The variations met with in brain-weight are very great, but it is doubtful if normal intellectual functions could be carried on in a brain which weighs less than 960 grammes. In microcephalic idiots brains of extremely small size are met with.

THE MENINGES OF THE BRAIN AND SPINAL CORD.

The brain and spinal cord are enclosed within three membranes, which are termed the meninges or meningeal membranes. From without inwards these are: (1) the dura mater, (2) the arachnoid mater, and (3) the pia mater. The space between the dura mater and the arachnoid receives the name of subdural space, while the much more roomy interval between the arachnoid and the pia mater is called the subarchnoid space.

Dura Mater.

The dura mater is a dense and thick fibrous membrane which possesses a very considerable degree of strength. Its arrangement within the cranial cavity is so different from that within the spinal canal that it is customary to speak of it as consisting of two parts, viz. a cranial and a spinal, although in adopting this subdivision it must be clearly understood that both portions are continuous with each other at the foramen magnum.

Cranial Dura Mater (dura mater cerebri).—The cranial dura mater is adherent to the inner surface of the cranial wall, and performs a double office. It serves as an internal periosteum for the bones which it lines and constitutes an envelope for the brain. Its inner surface, which bounds the subdural space, is smooth and glistening, and is covered by a layer of endothelial cells. The outer surface, when separated from the cranial wall, is rough, this being due to numerous fine fibrous processes and blood-vessels which pass between it and the bones. Its degree of

adhesion to the cranial wall differs considerably in different regions. To the vault of the cranium, except along the lines of the sutures, the connexion is by no means strong, and in the intervals between the fibrous processes which pass into the bone there are small lymph spaces (epidural spaces) where the outer surface of the membrane is covered by endothelial cells. So long as the sutures are open the dura mater is connected with the periosteum on the exterior of the skull, along the sutural lines, by a thin layer of fibrous tissue which intervenes between the bony margins. Around the foramen magnum, and to the floor of the cranium, the dura mater is very firmly adherent. This is more particularly marked in the case of the projecting parts of the cranial floor, as, for example, the petrous portions of the temporal bones, the clinoid processes, and so on. This firm adhesion in these regions is still further strengthened by the fact that the nerves, as they leave the cranium through the various foramina, are followed by sheaths of the fibrous dura

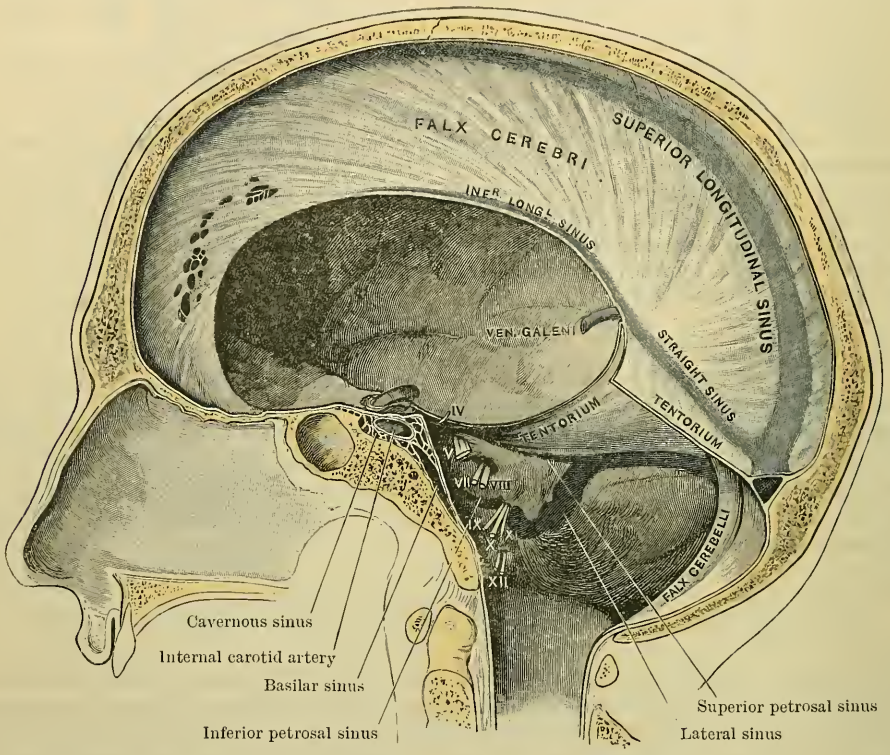


FIG. 477.—SAGITTAL SECTION THROUGH THE SKULL, A LITTLE TO THE LEFT OF THE MESIAL PLANE, to show the arrangement of the dura mater.

The cranial nerves are indicated by numerals.

mater. Outside the cranium these prolongations of the membrane blend with the fibrous sheaths of the nerves, and likewise become connected with the periosteum on the exterior of the skull. In the child, during the growth of the cranial bones, and also in old age, the dura mater is more adherent to the cranial wall than during the intermediate portion of life.

The cranial dura mater is composed of two layers intimately connected with each other, but yet capable of being demonstrated in most regions of the cranium. Along certain lines these two layers separate from each other so as to form channels lined by endothelium. These channels are the **venous blood-sinuses** which receive the blood from veins which come from various parts of the brain. They are described in the section dealing with the Vascular System.

Strong fibrous partitions or septa are given off along certain lines from the deep surface of the dura mater. These project into the cranial cavity, and subdivide it partially into compartments which all freely communicate with each other, and

each of which contains a definite subdivision of the brain. These septa are: (1) the falx cerebri; (2) the tentorium cerebelli; (3) the falx cerebelli; and (4) the diaphragma sellæ.

The **falx cerebri** is a sickle-shaped partition which descends in the great longitudinal fissure between the two hemispheres of the cerebrum. In front it is narrow, and attached to the crista galli of the ethmoid bone. As it is followed backwards it increases in breadth, and behind it is attached along the mesial plane to the upper surface of the tentorium. The anterior narrow part of the falx is frequently cribriform, and is sometimes perforated by apertures to such an extent that it almost resembles lace-work. Along each border it splits into two layers, so as to enclose a blood-sinus. Along its upper convex attached border runs the *great longitudinal sinus*; along its concave free border courses the much smaller *inferior longitudinal sinus*; whilst along its attachment to the tentorium is enclosed the *straight sinus.*

The **tentorium cerebelli** is a large crescentic partition of dura mater, which forms a membranous tent-like roof for the posterior cranial fossa, and thus intervenes between the posterior portions of the cerebral hemispheres and the cerebellum. It is accurately applied to the upper surface of the cerebellum. Thus its highest point is in front and in the mesial plane, and from this it slopes downwards towards its attached border. It is kept at a high degree of tension, and this depends on the integrity of the falx cerebri, which is attached to its upper aspect in the mesial plane.

The *posterior border* of the tentorium is convex, and is attached to the horizontal ridge which marks the deep surface of the occipital bone. Beyond this, on each side, it is fixed to the postero-inferior angle of the parietal bone, and then forwards along the superior border of the petrous portion of the temporal bone. From the internal occipital protuberance to the postero-inferior angle of the parietal bone this border encloses the *lateral blood-sinus*, whilst along the upper border of the petrous bone it encloses the *superior petrosal sinus.* The *anterior border* of the tentorium is sharp, free, and concave, and forms with the dorsum sellæ an oval opening shaped posteriorly like a pointed arch. This opening receives the name of the **incisura tentorii**, and within it is placed the mesencephalon, or the stalk of connexion between the parts which lie in the posterior cranial fossa and the cerebrum. Beyond the apex of the petrous part of the temporal bone the two margins of the tentorium cross each other like the limbs of the letter X; the free margin is continued forwards, to be attached to the anterior clinoid process, whilst the attached border proceeds inwards, to be fixed to the posterior clinoid process.

The **falx cerebelli** is a small, sickle-shaped process of dura mater placed below the tentorium, which projects forwards in the mesial plane from the internal occipital crest. It occupies the notch which separates the two hemispheres of the cerebellum posteriorly. Inferiorly it bifurcates into two small diverging ridges which gradually fade away as they are traced forwards on either side of the foramen magnum.

The **diaphragma sellæ** is a small circular fold of dura mater which forms a roof for the pituitary fossa. A small opening is left in its centre for the transmission of the infundibulum.

Spinal Dura Mater (dura mater spinalis).—In the spinal canal the dura mater forms a tube which encloses the spinal cord, and which extends from the foramen magnum above to the level of the second or third piece of the sacrum below. It is very loosely applied to the spinal cord and the nerve-roots which form the cauda equina; in other words, it is very capacious in comparison with the volume of its contents. Moreover, its calibre is not uniform. In the cervical and lumbar regions it is considerably wider than in the dorsal region, whilst in the sacral canal it rapidly contracts, and finally ends by blending with the filum terminale externum, the chief bulk of which it forms. At the upper end of the spinal canal the spinal dura mater is firmly fixed to the third cervical vertebra, to the axis vertebra, and around the margin of the foramen magnum. In the sacral canal the filum terminale externum, with which it blends, extends downwards to the back of the coccyx, to the periosteum of which it is fixed. The lower end of the tube is thus securely anchored and held in its place.

Within the cranial cavity the dura mater is closely adherent to the bones, and forms for them an internal periosteum. As it is followed into the spinal canal its two constituent layers separate. The inner layer is carried downwards as the long cylindrical tube which encloses the spinal cord. The outer layer, which is much thinner, becomes continuous behind and on each side of the foramen magnum with the periosteum on the exterior of the cranium, whilst in front it is prolonged downwards into the vertebral canal in connexion with the periosteum and ligaments on the anterior wall of the canal. The spinal dura mater, therefore, corresponds to the inner layer of the cranial dura mater, and to it alone. It is separated from the walls of the spinal canal by an interval, the **epidural space**, which is occupied by soft fat and a plexus of thin-walled veins. In connexion with the spinal dura mater there are no blood-sinuses such as are present in the cranial cavity, but it should be noted that the veins in the epidural space, placed as they are between the periosteum of the spinal canal and tube of dura mater, occupy the same morphological plane as the cranial blood-sinuses. Another feature which serves to distinguish the spinal dura mater from the cranial dura mater consists in the fact that it gives off from its deep surface no partitions or septa.

The cylindrical tube of spinal dura mater does not lie absolutely free within the vertebral canal. Its attachments, however, are of such a character that they in no way interfere with the free movement of the vertebral column. On either side the spinal nerve-roots, as they pierce the dura mater, carry with them into the intervertebral foramina tubular sheaths of the membrane, whilst in front loose fibrous prolongations—more numerous above and below than in the dorsal region—connect the tube of dura mater to the posterior common ligament of the vertebral column. No connexion of any kind exists between the dura mater and the posterior wall of the spinal canal.

When the interior of the tube of spinal dura mater is inspected, the series of apertures of exit for the roots of the spinal nerves is seen. These are ranged in pairs opposite each intervertebral foramen.

Viewed from the inside of the tube of dura mater, each of the two roots of a spinal nerve is seen to carry with it a special and distinct sheath. When examined on the outside, however, the appearance is such that one might be led to conclude that both roots are enveloped in one sheath of dura mater. This is due to the fact that the two sheaths are firmly held together by intervening connective tissue. The two tubular sheaths remain distinct as far as the ganglion on the posterior root, and then blend with each other.

Subdural Space.—The dura mater and the arachnoid mater are closely applied to each other, and the capillary interval between them is termed the subdural space. It contains a minute quantity of fluid, which is just sufficient in amount to moisten the opposed surfaces of the two bounding membranes.

The subdural space in no way communicates with the subarachnoid space. The fluid which it contains is led into the venous blood-sinuses around the Pacchionian bodies, and thus gains exit. The subdural space is carried outwards for a very short distance on the various nerves which are connected with the brain and the spinal cord, and it has a free communication with the lymph-paths present in these nerves. In the case of the optic nerve the sheath of dura mater is carried along its whole length, and with it the subdural space is likewise prolonged to the back of the eyeball.

The Arachnoidea.

The arachnoid mater is a very thin membrane, remarkable for its delicacy and transparency, which envelopes both the brain and the cord between the dura mater and the pia mater. The cranial part of the arachnoid mater or the **arachnoidea encephali**, except in the case of the great longitudinal and the Sylvian fissures, does not dip into the sulci on the surface of the brain. In this respect it differs from the pia mater. It bridges over the inequalities on the surface of the brain. Consequently, on the basal aspect of the encephalon it is spread out in the form of a very distinct sheet over the medulla, the pons Varolii, and the hollow which lies

in front of the pons, and in certain of these regions it is separated from the brain-surface by wide intervals.

The spinal part of the arachnoid mater or **arachnoidea spinalis**, which is directly continuous with the cranial arachnoidea, forms a loose wide investment for the spinal cord. This arachnoidal sac is most capacious towards its lower part, where it envelopes the lower end of the cord and the collection of long nerve-roots which constitute the cauda equina.

As the nerves, both from the brain and the cord, pass outwards they receive an investment from the arachnoid, which runs for a short distance upon them and then comes to an end.

Subarachnoid Space (cavum subarachnoidale).—The interval between the arachnoidea and the pia mater receives the name of the subarachnoid space. It

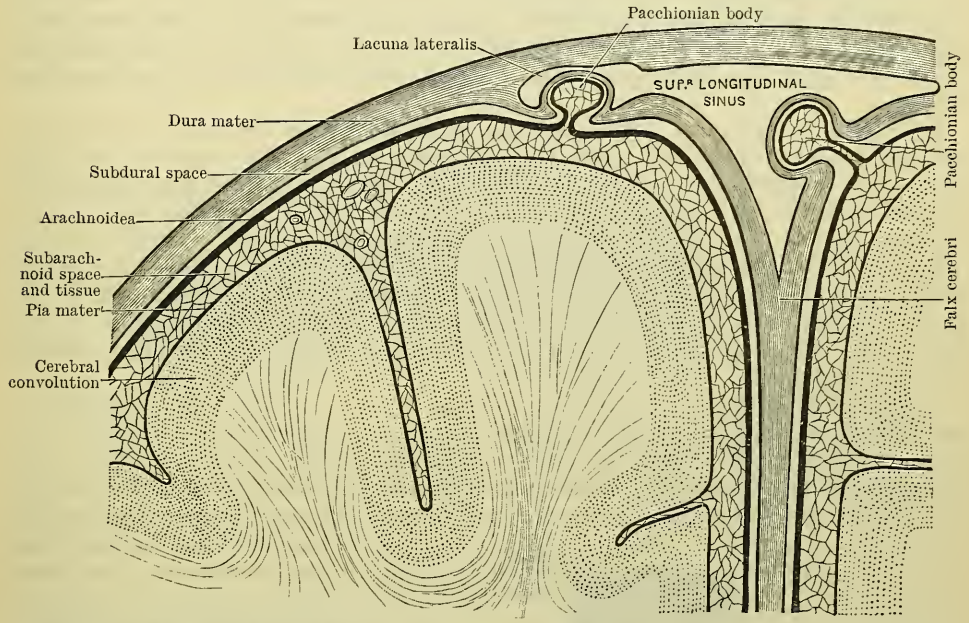


FIG. 478.—DIAGRAM to show the relations of the membranes of the brain to the cranial wall and the cerebral convolutions, and also of the Pacchionian bodies to the superior longitudinal sinus and the lateral lacunæ.

contains the cerebro-spinal fluid, and communicates freely through certain well-defined apertures with the ventricular cavities in the interior of the brain. Three of these (viz. the foramen of Majendie and another at the extremity of each lateral recess) are in connexion with the fourth ventricle; two are slit-like openings into the lateral ventricles, and are placed at the extremity of each descending horn.

Within the cranium the subarachnoid space is broken up by a meshwork of fine filaments and trabeculæ, which connects the two bounding membranes (viz. the arachnoidea and the pia mater) in the most intimate manner, and forms a delicate sponge-like interlacement between them. Where the arachnoidea passes over the summit of a cerebral convolution, and is consequently closely applied to the subjacent pia mater, the meshwork is so dense and the trabeculæ so short that it is hardly possible to discriminate between the two membranes. To all intents and purposes they form in these localities one lamina. In the intervals between the rounded margins of adjoining convolutions, however, distinct angular spaces exist, where the subarachnoid trabecular tissue can be studied to great advantage. These intervals on the surface of the cerebrum constitute numerous communicating channels which serve for the free passage of the subarachnoid fluid from one part of the brain to another. The larger branches of the arteries and veins of the brain traverse the subarachnoid space; their walls are directly connected with the subarachnoid trabeculæ, and are bathed by subarachnoid fluid.

In certain situations within the cranium the arachnoidea is separated from the

pia mater by intervals of considerable width and extent. These expanded portions of the subarachnoid space are termed **cisternæ subarachnoidales**. In these the subarachnoid tissue is much reduced. There is no longer a close meshwork; the trabeculæ connecting the two bounding membranes take the form of long filamentous intersecting threads which traverse the spaces. All the subarachnoid cisterns communicate in the freest manner with each other and also with the narrow channels on the surface of the cerebrum.

Certain of these cisterns require special mention. The largest and most conspicuous is the **cisterna magna**. It is formed by the arachnoid membrane bridging over the wide interval between the back part of the under surface of the cerebellum and the medulla. It is continuous through the foramen magnum with the posterior part of the wide subarachnoid space of the cord.

The **cisterna pontis** is the continuation upwards on the floor of the cranium of the anterior part of the subarachnoid space of the spinal cord. In the region of the medulla it is continuous behind with the cisterna magna, so that this subdivision of the brain, like the spinal cord, is surrounded by a wide subarachnoid space.

In front of the pons Varolii the arachnoidea bridges across between the projecting temporal lobes, and covers in the deep hollow in this region of the brain. This space is called the **cisterna basalis**, and within it are placed the large arteries which take part in the formation of the circle of Willis. Leading out from the cisterna basalis there are certain wide subarachnoid channels. Two of these are prolonged into the Sylvian fissures, and in these are accommodated the middle cerebral arteries. Anteriorly the basal cistern passes into a space in front of the optic chiasma, and from this it is continued into the great longitudinal fissure above the corpus callosum. In this subarachnoid passage the anterior cerebral arteries are lodged.

The spinal part of the subarachnoid space is a very wide interval which is partially subdivided into compartments by three incomplete septa. One of these is a mesial partition called the **septum posticum**, which connects the pia mater covering the posterior aspect of the cord with the arachnoid mater. In the upper part of the cervical region the septum posticum is imperfect, and is merely represented by some strands passing between the two membranes; in the lower part of the cervical region and in the dorsal region it becomes tolerably complete. The other two septa are formed by the **ligamenta denticulata** which spread outwards from either side of the spinal cord. These will be described with the pia mater.

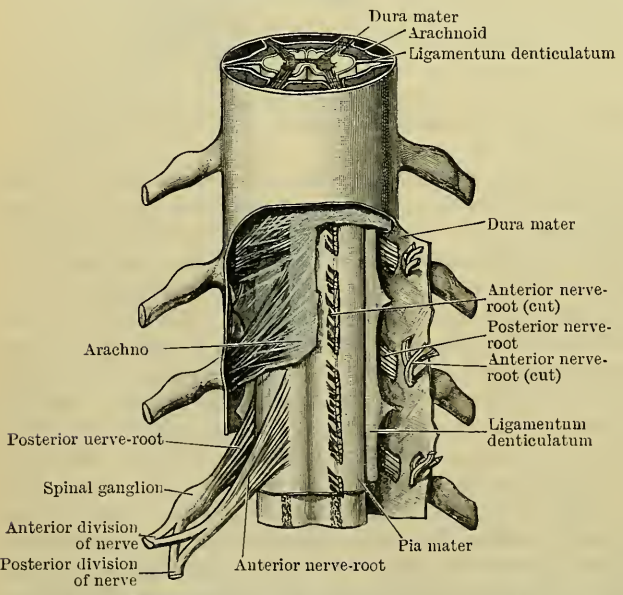


FIG. 479.—MEMBRANES OF THE SPINAL CORD, AND THE MODE OF ORIGIN OF THE SPINAL NERVES.

Pacchionian Bodies (granulationes arachnoidales).—When the surface of the dura mater is inspected after the removal of the calvaria, a number of small fleshy-looking excrescences, purplish-red in colour, are seen ranged in clusters on either side of the superior longitudinal sinus, and when this sinus is opened they are also observed protruding in considerable numbers into its interior. These are the Pacchionian bodies, and they are also found in smaller number and distinctly smaller size in connexion with other blood-sinuses, such as the lateral sinus, the

straight sinus, and the cavernous sinus. At first sight they appear to belong to the dura mater, but in reality they are projections from the arachnoidea. In the child they are exceedingly small and rudimentary, and it is only as life advances that they become large and conspicuous.

Each Pacchionian body is a bulbous protrusion of the arachnoid membrane. It is attached to the arachnoidea by a narrow pedicle, and into its interior is prolonged through this a continuation of the subarachnoid space and its characteristic meshwork. The Pacchionian bodies do not pierce the dura mater. As they push their way into a blood-sinus they carry before them a thin covering continuous with the sinus wall. On either side of the superior longitudinal sinus there are a number of irregular spaces in the dura mater which communicate with the sinus either by a small aperture or a narrow channel. These spaces are called the **parasinoidal sinuses** or the **lacunæ laterales**, and certain of the meningeal veins and some of the diploic veins open into them. Pacchionian bodies push themselves into the parasinoidal sinuses from below in such a manner that they receive a

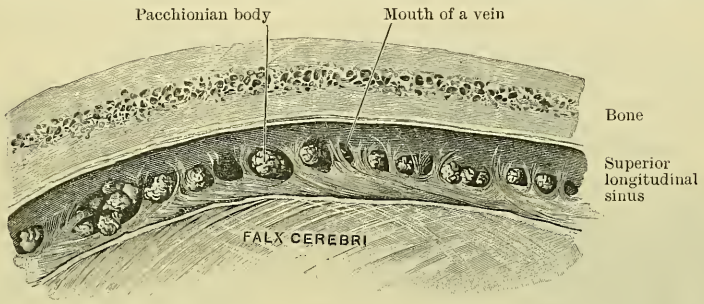


FIG. 480.—MESIAL SECTION THROUGH THE CRANIAL VAULT IN THE FRONTAL REGION. Displays a portion of the superior longitudinal sinus and the Pacchionian bodies protruding into it (enlarged).

complete covering from the layer of dura mater which forms the sinus floor. Nor does the bone escape. As the Pacchionian bodies enlarge they cause absorption of the cranial wall, and small pits are hollowed out on its deep surface for their reception. It must be clearly understood, however, that in such cases the Pacchionian body is separated from the bone by the following:—(1) A continuation round the Pacchionian body of the subdural space; (2) the thinned floor of the parasinoidal sinus; (3) the lumen of the sinus; and (4) the greatly thinned upper wall of the sinus.

The Pacchionian bodies have a special function to perform. Through them fluid can pass from the subarachnoid space into the venous sinuses with which they stand in connexion. Whenever the pressure of blood in the sinuses is lower than that of the fluid in the subarachnoid space and the ventricles of the brain, the cerebro-spinal fluid filtrates through the Pacchionian bodies into the blood-sinuses. This is not the only way that subarachnoid fluid may obtain exit. The subarachnoid space is carried outwards for a short distance on the nerves in connexion with their arachnoidal sheaths, and communicates with the lymph channels of the nerves. This connexion is more complete in the case of the olfactory, the optic, and the auditory nerves, than in other nerves. A very free communication between the subarachnoid space and the lymphatics of the nasal mucous membrane is said to exist.

THE PIA MATER.

The pia mater forms the immediate investment of the brain and cord. It is a delicate and very vascular membrane.

Pia mater encephali.—The pia mater which covers the brain is finer and more delicate than that which clothes the spinal cord. It follows closely all the inequalities on the surface of the brain, and in the case of the cerebrum it dips into each sulcus in the form of a fold which lines it completely. On the cerebellum the relation is not so intimate; it is only into the larger fissures that it penetrates in the form of folds.

The larger blood-vessels of the brain lie in the subarachnoid space. The finer twigs ramify in the pia mater before they proceed into the substance of the brain. As they enter they carry with them sheaths derived from the pia mater. When a portion of the membrane is raised from the surface of the encephalon, numerous fine processes are withdrawn from the cerebral surface. These are the blood-vessels with their sheaths, and they give the deep surface of the pia mater a rough and flocculent appearance.

As the pia mater is carried over the lower part of the roof or posterior wall of the fourth ventricle of the brain it receives the name of the **tela choroidea inferior**, and it is in connexion with this portion of the pia mater that the choroid plexuses of that cavity are developed. The tela choroidea superior or velum interpositum is a fold of pia mater which is invaginated into the brain, so that it comes to lie over the third ventricle and project in the shape of choroid plexuses into the lateral ventricles. This invagination requires special notice.

The **velum interpositum** (tela choroidea superior) is a double layer or fold of pia mater which intervenes between the body of the fornix which lies above it and the epithelial roof of the third ventricle, and the two optic thalami which lie below it. Between its two layers are blood-vessels, and some subarachnoidal trabecular tissue. In shape the velum interpositum is triangular, and the narrow anterior end or apex reaches forwards as far as the foramina of Monro. The base lies under the splenium of the corpus callosum, and here the two layers of the velum separate and become continuous with the investing pia mater on the surface of the brain by passing out through a cleft called the **transverse fissure.**

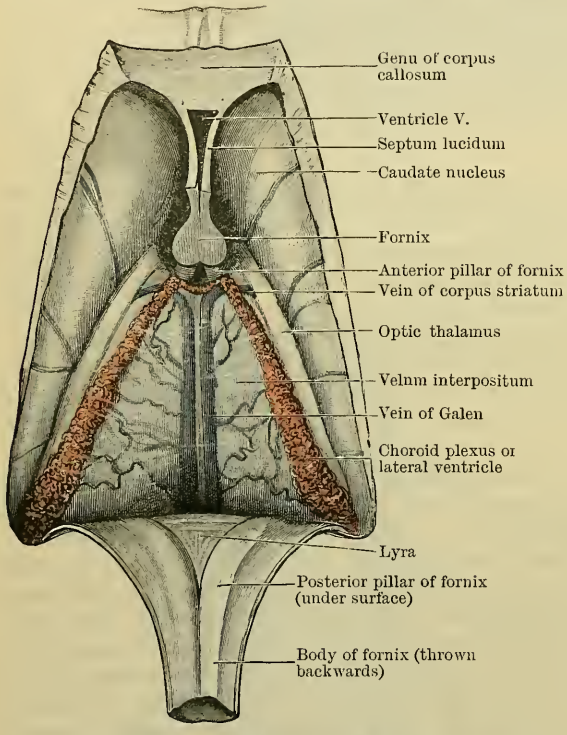


FIG. 481.—DISSECTION TO SHOW THE VELUM INTERPOSITUM, AND THE PARTS IN IMMEDIATE RELATION TO IT.

Along each lateral margin the velum interpositum is bordered by the choroid plexus of the body of the lateral ventricle, which projects into the ventricular cavity from under cover of the free lateral margin of the fornix. It should be borne in mind that the epithelial lining of the ventricle gives a complete covering to the choroid plexus. Posteriorly the choroid plexus is continuous with the similar structure in the descending horn of the ventricle, whilst in front it narrows greatly, and becomes continuous across the mesial plane with the corresponding plexus of the opposite side, behind the epithelial layer which lines the foramen of Monro. From this median junction two much smaller choroid plexuses run backwards on the under surface of the velum interpositum, and project downwards into the third ventricle. These are the choroid plexuses of the third ventricle.

The most conspicuous blood-vessels in the velum interpositum are the two **veins of Galen**, which run backwards, one on either side of the mesial plane. In front, each is formed at the apex of the fold by the union of the vein of the corpus striatum and a large vein issuing from the choroid plexus; behind, they unite to form the **vena magna Galeni**, and this pours its blood into the anterior end of the straight sinus (Fig. 477, p. 598).

The continuous cleft in the brain through which the velum interpositum and the choroid plexuses of the two descending horns of the lateral ventricles are

introduced into the interior of the brain is sometimes called the **transverse fissure**. It consists of an upper intermediate part and two lateral parts. The former passes forwards between the corpus callosum and the fornix above and the roof of the third ventricle and the optic thalami below. It is limited on either side by the epithelial covering of the choroid plexuses, which shuts out these structures from the cavity of the lateral ventricles. The lateral part is the **choroidal fissure**. This is continuous with the intermediate part, and has already been described in connexion with the descending horn of the lateral ventricle (p. 578).

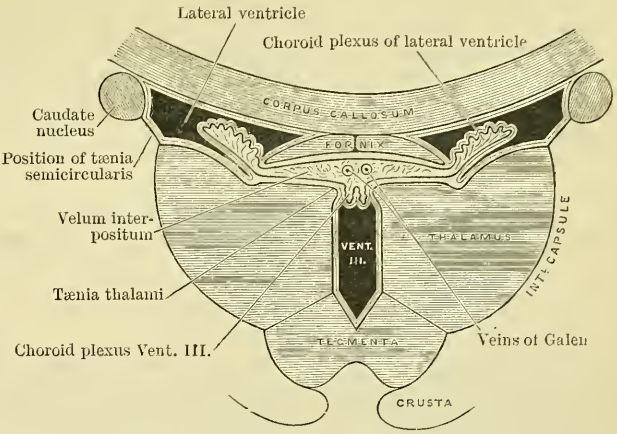


FIG. 482.—DIAGRAMMATIC CORONAL SECTION through the optic thalami, and the parts in immediate relation to them. The intermediate part of the great transverse fissure holding the velum interpositum is seen, and also the manner in which this fissure is shut out from the lateral ventricles by the epithelium which covers the choroid plexus on each side.

Pia mater spinalis.—The pia mater of the cord is thicker and denser than that of the brain. This is largely due to the addition of an outside fibrous layer, in which the fibres run chiefly in the longitudinal direction. The pia mater is very firmly adherent to the surface of the cord, and in front it sends a fold into the antero-median fissure of the cord. The septum which occupies the postero-median fissure is likewise firmly attached to its deep surface. In front of the antero-median furrow of the cord the pia mater is thickened in the form of a longitudinal glistening band, termed the **linea splendens**, which runs along the whole length of the cord, and blends with the filum terminale below. The blood-vessels of the spinal cord lie between the two layers of the pia mater.

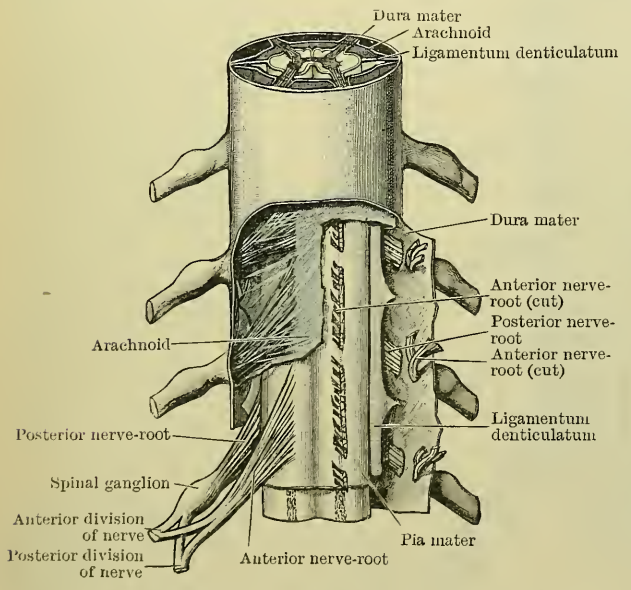


FIG. 483.—MEMBRANES OF THE SPINAL CORD, AND THE MODE OF ORIGIN OF THE SPINAL NERVES.

The nerves which leave both the brain and cord receive closely-applied sheaths from the pia mater. These blend with the connective-tissue sheaths of the nerves.

The **ligamentum denticulatum** is a strong fibrous band which stretches out like a wing from the pia mater on either side of the spinal cord, so as to connect the pia mater with the dura mater. The pial or inner attachment of the ligament extends in a continuous line between the anterior and posterior nerve-roots, from the level of the foramen magnum above to the level of the first lumbar vertebra below. Its outer margin is serrated or denticulated, and for the most part free. From twenty to twenty-two denticulations may be recognised. They occur in the intervals between the spinal nerves, and pushing the arachnoid before them, they

are attached by their pointed ends to the inner surface of the dura mater. The ligamenta denticulata partially subdivide the wide subarachnoid space in the spinal canal into an anterior and a posterior compartment. The anterior nerve-roots traverse the anterior compartment, whilst the posterior nerve-roots traverse the posterior compartment. Further, the posterior compartment is imperfectly subdivided into a right and a left lateral part by the septum posticum.

By means of the ligamenta denticulata the spinal cord is suspended in the middle of the tube of dura mater.

THE PERIPHERAL NERVES AND THE SYMPATHETIC NERVOUS SYSTEM.

By A. M. Paterson.

Arising from the brain and spinal cord respectively, the cranial and spinal nerves are responsible, collectively, for the central localisation of peripheral stimuli, or for the transmission peripherally of central impulses. The sense organs and the somatic regions of the body are in direct communication by the nerves with the brain and spinal cord. The splanchnic area, and the viscera which it contains, are governed by nerves connected with the central nervous system. By means of the sympathetic nervous system, the nerves from the cerebro-spinal system are directed to their several destinations in the splanchnic area: and connexions are effected with the roots of the nerves on the one hand, and through their peripheral branches, with the somatic region, on the other hand.

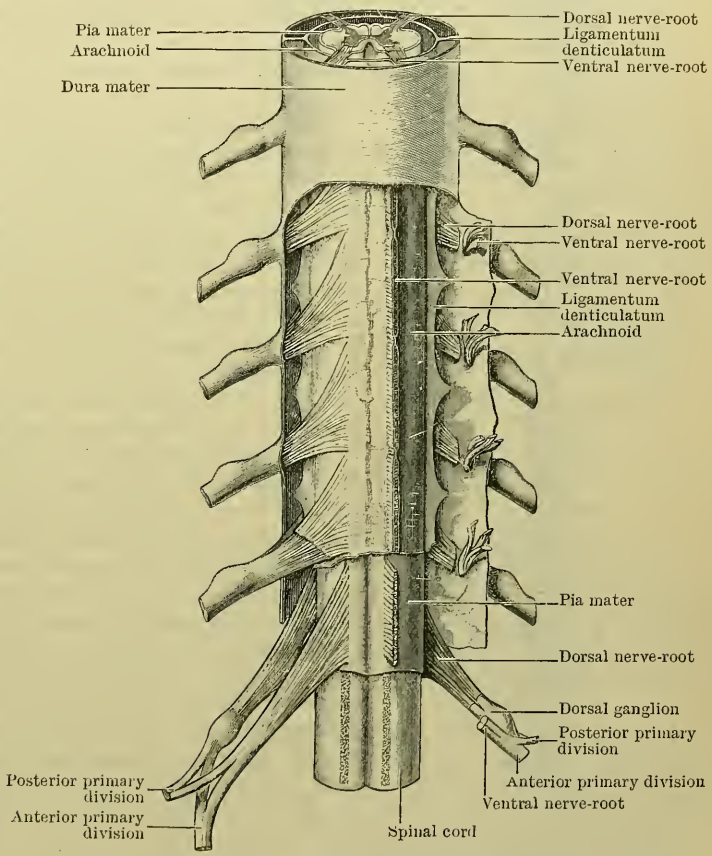


Fig. 484.—Scheme of the Arrangement of the Membranes of the Spinal Cord and the Roots of the Spinal Nerves.

THE SPINAL NERVES.

The **spinal nerves** are arranged in pairs, of which there are usually thirty-one. Each nerve arises by two roots from the spinal cord, which separately pierce the dura mater. Enclosed in a tubular investment of this membrane, the nerve emerges from the spinal canal through the intervertebral foramen, and is distributed to the trunk and limbs in a manner to be described below.

The nerves are designated **cervical, thoracic, lumbar, sacral,** and **coccygeal,** in relation to the vertebræ between which they emerge from the spinal canal. Each nerve appears below the corresponding vertebra, except the first of the cervical series,

which passes out of the spinal canal between the occipital bone and the atlas. There are thus *eight* cervical nerves (the last appearing between the seventh cervical and first thoracic vertebræ); there are *twelve* thoracic, *five* lumbar, *five* sacral, and *one* coccygeal nerve, all appearing below the corresponding vertebræ.

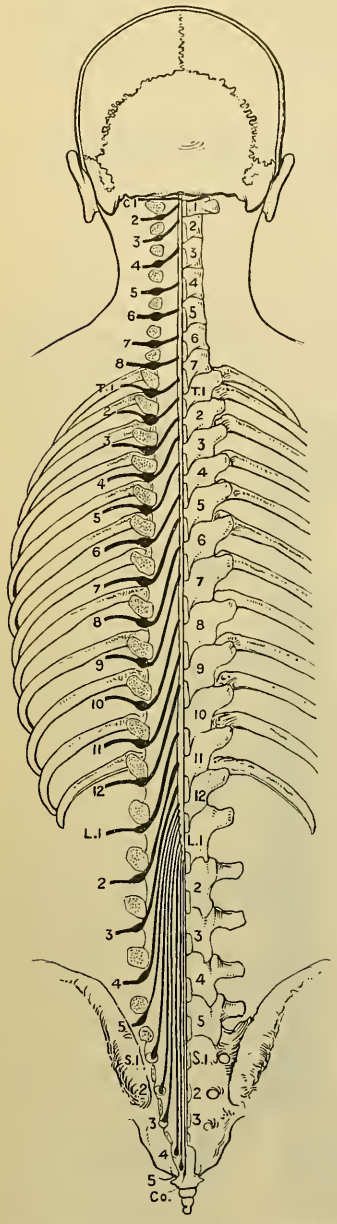


Fig. 485.—Diagrammatic Representation of the origin of the Spinal Nerves, showing the position of their roots and ganglia respectively in relation to the spinal column. The nerves are shown as thick black lines on the left side.

The thirty-first nerve is occasionally absent; and there are sometimes one or two additional pairs of minute filaments below the thirty-first, which, however, do not emerge from the spinal canal. These are rudimentary caudal nerves.

The size of the spinal nerves varies extremely. The largest are those which take part in the formation of the great nerve-trunks for the supply of the limbs (lower cervical and first thoracic, and lower lumbar and upper sacral nerves); and of these the nerves destined for the lower limbs are the larger. The coccygeal nerve is the smallest of the spinal nerves; the thoracic nerves (except the first) are much more slender than the limb nerves; and the cervical nerves diminish in size from below upwards.

Origin of the Spinal Nerves.—Each spinal nerve is attached to the spinal cord by **two roots**, called respectively **dorsal** (posterior) and **ventral** (anterior).

The **dorsal root** is larger than the ventral root; it contains a larger number of rootlets, and the individual rootlets are of larger size than in the ventral root. It has a vertical linear attachment to the postero-lateral sulcus of the spinal cord. The rootlets of contiguous dorsal roots are in close relation, and, in some instances, overlap. The dorsal root separates as it passes away from the cord into two bundles, both of which become connected with the inner end of a **spinal ganglion**. From the outer end of this ganglion the dorsal root proceeds to its junction with the ventral root in the intervertebral foramen.

The **spinal ganglia** are found on the dorsal roots of all the spinal nerves. (In the case of the first cervical or sub-occipital nerve, the spinal ganglion may be rudimentary or absent; and the dorsal root itself may be wanting, or derived from the spinal accessory nerve.) They occupy the intervertebral foramina, except in the case of the sacral and coccygeal nerves, the ganglia of which lie *within* the vertebral canal: and the first and second cervical nerves, the ganglia of which lie upon the neural arches of the atlas and axis respectively. With the exception of the coccygeal ganglia they are outside the cavity of the dura mater, but are invested by the membrane. The ganglia are of ovoid form, bifurcated in some cases at their inner ends. They consist of unipolar nerve-cells, whose processes, after a very short course, divide into central (root) and peripheral (trunk) fibres. The central fibres form the portion of the root entering the spinal cord; the peripheral fibres are continued in an outward direction from the ganglion into the spinal nerve.

Accessory spinal ganglia (ganglia aberrantia).—Between the spinal ganglion and the spinal cord small collections of cells are occasionally found on the dorsal roots, either as scattered cells or distinct ganglia. They are most frequently met with on the dorsal roots of the lumbar and sacral nerves.

The **ventral root** is smaller than the dorsal root. It arises from the anterior surface of the spinal cord (*anterior root zone*) by means of scattered bundles of nerve-fibres, which occupy a greater horizontal area and are more irregular in their arrangement than the fascicles of the dorsal root. It possesses no ganglion in its course. The rootlets sometimes overlap, and are not unfrequently connected with neighbouring rootlets above and below.

The dorsal and ventral roots, from their attachment to the spinal cord, proceed outwards in the spinal canal towards the intervertebral foramina, where they unite to form the spinal nerve. The direction of the roots of the first two nerves is upwards and outwards; the roots of the remaining nerves course obliquely downwards and outwards, the obliquity gradually increasing until, in the case of the lower lumbar, the sacral and coccygeal nerve-roots, their course is vertically downwards in the spinal canal. The collection of nerve-roots which occupies the lower part of the canal below the first lumbar vertebra, and comprises all the nerve-roots below those of the first lumbar nerve, is designated the **cauda equina**. They arise from the lumbar enlargement and conus medullaris, and surround the filum terminale of the spinal cord.

Within the spinal canal the nerve-roots are in relation with the meninges of the cord, and are separated from one another by the ligamentum denticulatum, and, in the neck, by the spinal part of the spinal accessory nerve. Each receives a covering of pia mater, continuous with the neurilemma; the arachnoid invests each root as far as the point where it meets with the dura mater; and each root pierces the dura mater separately. The two roots are thereafter enclosed in a single tubular sheath of dura mater, in which is included the spinal ganglion of the dorsal root. The spinal nerve thus formed lies in the intervertebral foramen, except in the case of the first two cervical and the sacral and coccygeal nerves.

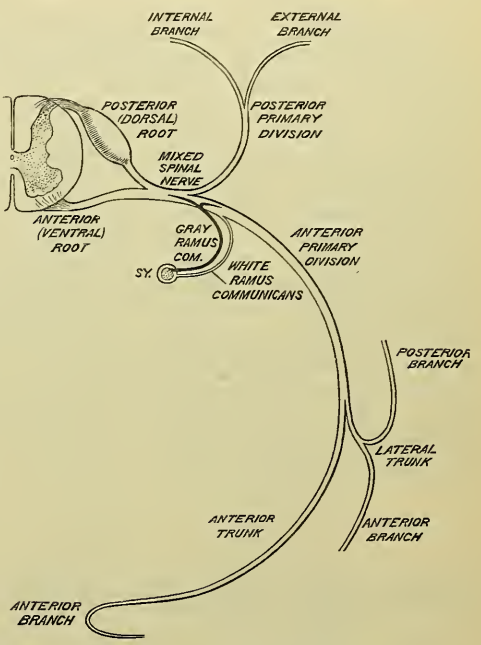


FIG. 486.—SCHEME OF THE DISTRIBUTION OF A TYPICAL SPINAL NERVE.

Divisions of a Spinal Nerve.—After emerging from the intervertebral foramen the nerve immediately divides into two primary divisions, named respectively the **posterior** and **anterior primary divisions**. Just before its division each nerve gives off a minute **recurrent branch**, which re-enters the vertebral canal after effecting a junction with a branch from the sympathetic cord, and is distributed to the spinal cord and its membranes.

The **posterior** and **anterior primary divisions** of the spinal nerve are responsible for the innervation of the skeletal muscles and the skin covering the trunk and limbs. They are thus, properly speaking, the somatic branches of the spinal nerve.

In relation to certain of the nerves, a series of much smaller branches exist which are connected with the sympathetic system (Fig. 486, *SY*), in a way to be described later. These constitute the **white rami communicantes**, and may be termed the **visceral divisions** of the spinal nerves. They are derived from the anterior primary divisions of the nerves, and receive their fibres mainly from the ventral roots, though, at least in the case of certain nerves, from the dorsal roots as well. These nerves are directed inwards from the intervertebral foramen over the vertebral column, and, becoming connected with the sympathetic cord, convey spinal fibres to the organs and tissues in the splanchnic area.

The posterior and anterior primary divisions of the nerves contain fibres from

both dorsal and ventral roots. Indeed, each root can be seen, on removal of its sheath, to divide into two portions, of which one portion enters into the formation of the posterior, the other into the formation of the anterior primary division. The posterior primary divisions, with the exception of the first two, are smaller than the anterior primary divisions; and they are, generally speaking, responsible for the innervation of the skin and muscles of the back. They do not supply the muscles of the limbs; although in their cutaneous distribution they are prolonged on to the back of the head, the shoulder, and the buttock. They form two small plexuses —the **posterior cervical** and the **posterior sacral plexuses**. The anterior primary divisions are, with the exception of the first two cervical nerves, much larger than the posterior primary divisions. They supply the sides and fore-parts of the body, the limbs, and the perineum. For the most part they have a complicated arrangement. The thoracic or intercostal nerves alone have a simple mode of distribution; the other nerves give rise to the three great **plexuses—cervical, brachial,** and **lumbo-sacral**.

Distribution of the Spinal Nerves.—The distribution, like the origin of the posterior and anterior primary divisions of the spinal nerves, presents primarily and essentially a segmental arrangement, masked and in some cases obliterated by developmental changes which have occurred in the parts supplied. In no region can a single nerve be traced to a complete segment. In the trunk between the limbs the nearest approach to a complete girdle is formed by such a nerve as the sixth thoracic nerve. In its cutaneous distribution it forms a perfect belt, the nerve by its posterior and anterior primary divisions supplying a distinctly segmental area from the middle line of the trunk behind to the sternum in front. Its muscular distribution, also, is almost perfectly segmental. The anterior primary division supplies, unaided, the intercostal muscles of the segment in which it lies. The posterior primary division supplies muscles in the back, not, however, in a strictly segmental manner, on account of the fact that the segmental myotomes have fused together in the back to give rise to complex longitudinal muscles, which are together supplied by the series of muscular branches derived from the posterior primary divisions of contiguous nerves. In other regions greater changes cause more marked deviations from a simple segmental type of distribution and give rise to the various plexuses, by which the trunk, and more particularly the limbs, are innervated.

POSTERIOR PRIMARY DIVISIONS OF THE SPINAL NERVES.

The posterior primary divisions of the spinal nerves are distributed generally to the skin of the back of the trunk, the back of the head, the shoulder and the buttock, and to the longitudinal muscles of the back, but not to the muscles of the limbs.

Each posterior primary division divides as a rule into two parts, an **internal** and an **external trunk** (Fig. 486, p. 609). In the upper half of the body the internal trunks generally supply the cutaneous branches, while the external trunks are purely muscular nerves. In the lower part of the body the opposite is the case: the external trunks provide the cutaneous nerves and the internal trunks are distributed entirely to muscles. The cutaneous branches have a different course in the two cases. In the upper half of the back they course inwards and backwards beneath and among the muscles to within a short distance of the spinous processes of the vertebræ, close to which they become superficial. They then extend outwards in the superficial fascia. In the lower half of the back the cutaneous nerves are directed downwards and outwards among the muscles, and become superficial at a greater distance from the middle line.

CERVICAL NERVES.

First Cervical Nerve (n. sub-occipitalis).—It has already been pointed out that the dorsal root of this nerve may be rudimentary, or even absent altogether. Its posterior primary division is larger than the anterior primary division; it does not divide into internal or external branches, and it does not directly supply any cutaneous branch.

Passing backwards in the space between the occipital bone and the posterior arch of the atlas, the nerve occupies the sub-occipital triangle, and is placed below and behind the vertebral artery, and under cover of the complexus muscle. It supplies the following branches:—

(*a*) **Muscular branches** to the complexus, recti capitis postici, major and minor, and obliqui, superior and inferior.

(*c*) A **communicating branch** descends to join the second cervical nerve.

The communicating branch may arise in common with the nerve to the obliquus inferior, and reach the second cervical nerve by piercing or passing over or beneath the obliquus inferior. Or it may accompany the nerve to the complexus, and communicate with the great occipital nerve, after piercing that muscle.

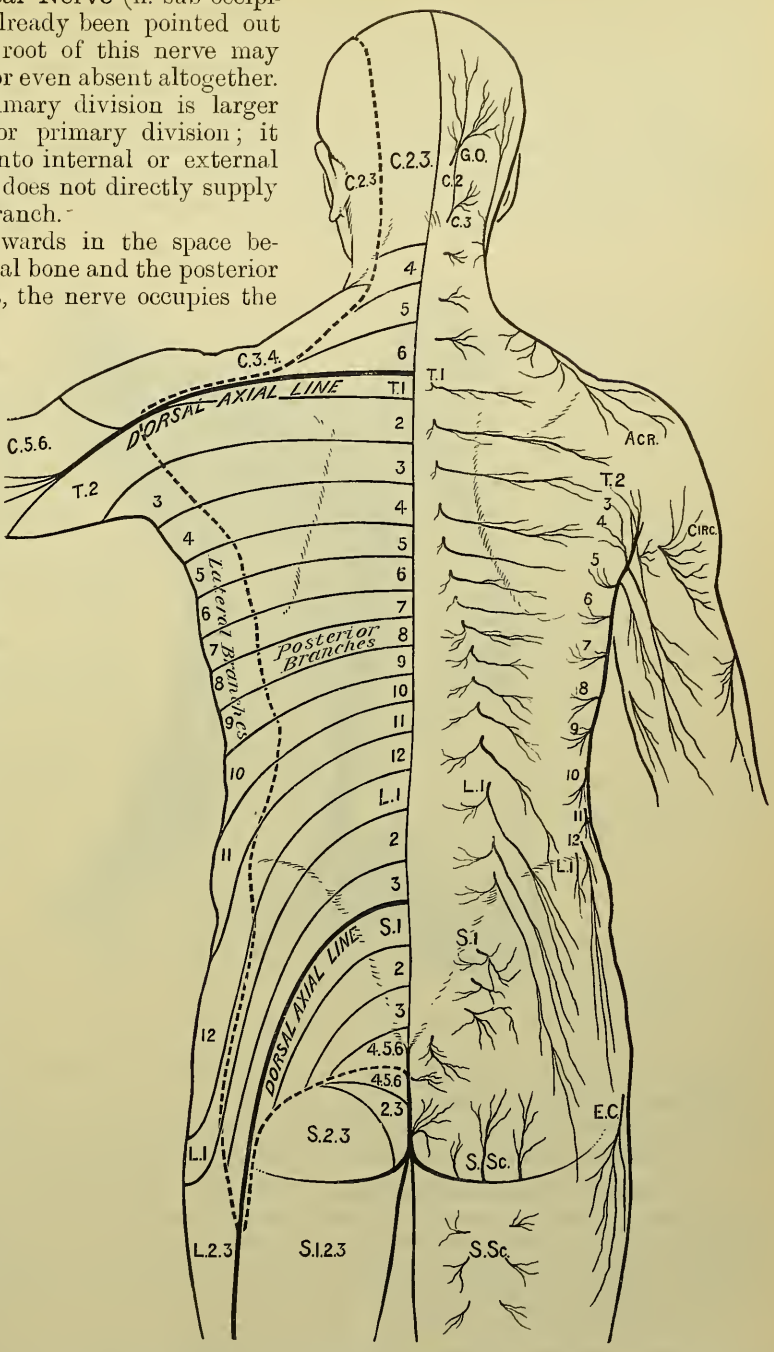


Fig. 487.—The Distribution of Cutaneous Nerves on the Back of the Trunk.

On one side the distribution of the several nerves is represented, the letters indicating their nomenclature.

G.O (C.2), Great occipital; C.3, Least occipital; T.1 *et seq.*, Posterior primary divisions of thoracic nerves; L.1 *et seq.*, Posterior primary divisions of first three lumbar nerves; S.1 *et seq.*, Posterior primary divisions of sacral nerves; Acr, Acromial branches from cervical plexus; T.2-12, Lateral branches of thoracic nerves; Circ, Cutaneous branches of circumflex nerve; L.1, Iliac branch of ilio-hypogastric nerve; E.C, External cutaneous nerve; S.Sc, Small sciatic nerve.

On the other side a schematic representation is given of the areas supplied by the above nerves, the numerals indicating the spinal origin of the branches of distribution to each area.

Second Cervical Nerve.—The posterior primary division of this nerve is larger than the corresponding anterior primary division. It passes backwards between the atlas and axis, and in the interval between the obliquus inferior and the semispinalis colli muscles, under cover of the complexus muscle. In this situation the nerve gives off several small muscular and communicating branches. The main trunk, after piercing the complexus and trapezius muscles, accompanies the occipital artery to the scalp as the **great occipital nerve** (n. occipitalis major). This is the chief cutaneous nerve for the back part of the scalp. It enters the superficial fascia at the level of the superior curved line of the occipital bone and about an inch from the external occipital protuberance. Ramifying over the surface, it supplies the skin of the scalp as far as the vertex. It *communicates* on

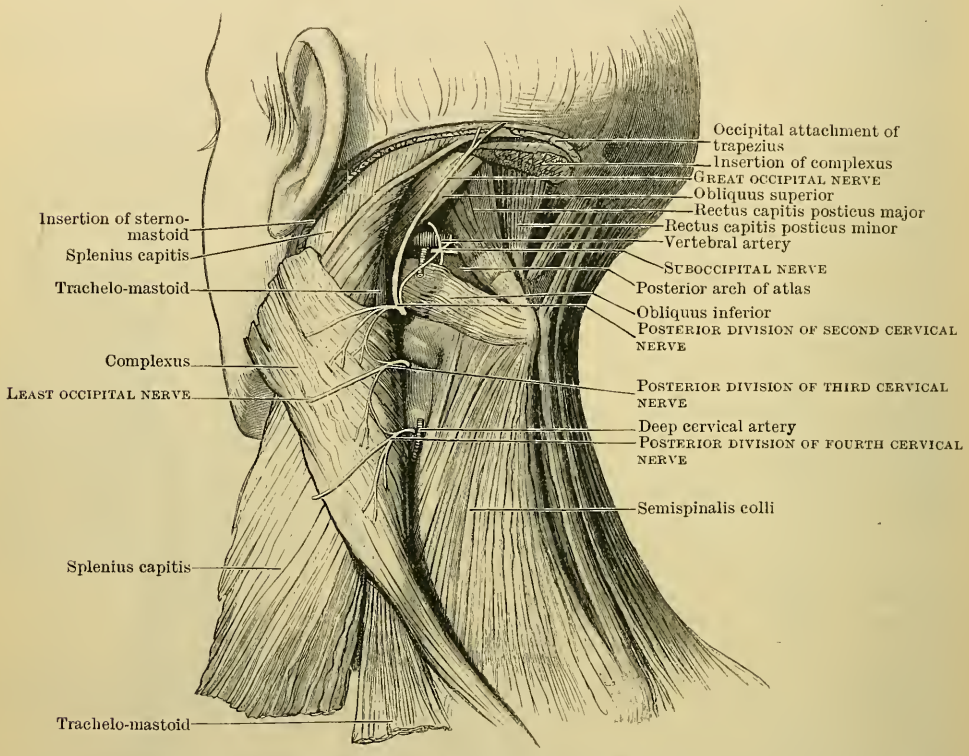


FIG. 488.—POSTERIOR CERVICAL PLEXUS.

the scalp with the following nerves: great auricular, small occipital, posterior auricular, and least occipital.

The **muscular branches** of the second cervical nerve are destined for the complexus, obliquus inferior, semispinalis colli, and multifidus spinæ.

Its **communicating branches** form the **posterior cervical plexus.** Descending over the posterior arch of the atlas is a branch from the sub-occipital nerve which forms a loop or network with a corresponding branch of the second nerve. From this loop twigs are supplied to the surrounding muscles. A similar loop is formed by a communication between branches of the second and third nerves, from which muscles are also supplied. Occasionally an additional loop is formed between branches of the third and fourth nerves.

Third Cervical Nerve.—This is much smaller than the second nerve. Near its origin it forms a loop of communication with the second, and it may give off a similar communicating branch to the fourth nerve. The main trunk divides into internal cutaneous and external muscular branches. The external muscular branch enters contiguous muscles; the internal cutaneous branch passes backwards and inwards, and becomes superficial as the **third** or **least occipital nerve** (n. occipitalis minimus), close to the middle line of the neck. It supplies fine branches to the neck and scalp, and communicates with the great occipital nerve.

The **fourth, fifth, and sixth cervical nerves** are still smaller. Beneath the complexus each divides into external muscular and internal cutaneous branches. The muscular branches supply neighbouring muscles; the cutaneous branches are small nerves, which, passing backwards, become superficial close to the middle line. They supply the skin of the back of the neck. The sixth is the smallest, and its cutaneous branch is minute, and may be absent altogether. In certain cases the fourth nerve forms, with the third, a loop of communication from which muscles are supplied.

Seventh and Eighth Cervical Nerves.—These are the smallest of the posterior primary divisions of the cervical nerves. They give off ordinarily no cutaneous branches, and end in the deep muscles of the back.

THORACIC NERVES.

The posterior primary division of each thoracic nerve divides into an **internal** and **external branch**. In the case of the upper six thoracic nerves the internal branches are chiefly distributed as cutaneous nerves,—only giving off small muscular branches—while the external branches are wholly muscular in their distribution; in the case of the lower six thoracic nerves the opposite is the case. In all cases the muscular branches serve to innervate the longitudinal muscles of the back. The distribution of the cutaneous branches is different in the upper and lower part of the back. The *upper six* or *seven* thoracic nerves innervate the skin of the scapular region. The **internal cutaneous branches**, after passing backwards from their origin among the dorsal muscles, reach the surface near the spines of the vertebræ and are directed almost horizontally outwards over the vertebral border of the scapula. The first is small; the second is very large and reaches to the acromion process. The rest diminish in size, from above downwards, and become more and more oblique in direction. The **external cutaneous branches** of the *lower five* or *six* thoracic nerves are directed from their origin obliquely downwards and outwards among the parts of the erector spinæ muscle. Becoming cutaneous by piercing the latissimus dorsi at some distance from the middle line, they supply the skin of the back in the lower part of the chest and loin, the lowest nerves (eleventh and twelfth) reaching over the iliac crest on to the buttock. The lower nerves often subdivide into two branches before or after their emergence from the latissimus dorsi muscle.

LUMBAR NERVES.

First three Lumbar Nerves.—The posterior primary divisions of the first three lumbar nerves subdivide into internal and external branches, in the same way as the lower thoracic nerves. The internal branches are muscular and innervate the deep muscles of the back. The external branches are chiefly cutaneous. They are directed obliquely downwards and outwards among the fibres of the erector spinæ and become superficial by piercing the vertebral aponeurosis, just above the iliac crest and a short distance in front of the posterior iliac spine. They are then directed downwards in the superficial fascia of the buttock, and supply a lengthy strip of skin, extending from the middle line above the iliac crest to a point below and behind the great trochanter of the femur.

The **fourth and fifth lumbar nerves** (like the last two cervical nerves) usually supply only muscular branches to the longitudinal muscles of the back. The fifth nerve in many cases sends a minute branch to form a loop of connexion with the posterior primary division of the first sacral nerve (**posterior sacral plexus**).

SACRAL AND COCCYGEAL NERVES.

The posterior primary divisions of the sacral nerves issue from the posterior sacral foramina. As in the case of the thoracic and lumbar nerves, the upper sacral nerves differ from the lower in their distribution.

The **first three sacral nerves** supply internal muscular branches for the multifidus spinæ, and external cutaneous branches which pierce the fibres of the sacro-sciatic ligament and the gluteus maximus muscle, and supply the skin over

the back of the sacrum and contiguous part of the buttock, giving rise to the posterior sacral plexus.

The **posterior sacral plexus** consists, like the posterior cervical plexus, of loops or plexiform communications over the back of the sacrum between the posterior primary divisions of the first three sacral nerves, to which are frequently joined branches of the last lumbar nerve and fourth sacral nerve. From these loops branches proceed to supply the multifidus spinæ muscle; others, piercing the great sacro-sciatic ligament, form secondary loops beneath the gluteus maximus muscle. From the secondary loops, two or more cutaneous branches arise, which, after traversing the muscle, supply the skin over the sacrum and inner part of the buttock.

Posterior Sacro-coccygeal Nerve.—The posterior divisions of the fourth and fifth sacral nerves do not divide into internal and external branches. They unite together to form a cord which, descending behind the coccyx, receives the minute posterior primary division of the coccygeal nerve. The union of the three nerves constitutes the **posterior sacro-coccygeal nerve**, which, after perforating the sacro-sciatic ligament, is distributed to the skin in the neighbourhood of the coccyx. It supplies no muscles. This nerve is the representative of the **superior caudal trunk** of tailed animals.

Morphology of the Posterior Primary Divisions.

There are several points of morphological interest in relation to the posterior primary divisions of the spinal nerves.

1. **Muscular Distribution.**—In their muscular distribution they are strictly limited to the longitudinal muscles of the back: namely, those associated with the axial skeleton alone.

2. **Cutaneous Distribution.**—Their cutaneous distribution represents two points of interest.

A. In the first place, while the skin of the back is supplied in a regularly segmental manner by the several nerves, certain of them fail to reach the surface at all. The absence of a cutaneous branch from the sub-occipital nerve may be due either to the absence of a perfect dorsal root, or to its communication with the second nerve. The other nerves, which do not usually supply the skin, are the seventh and eighth cervical, and the fourth and fifth lumbar nerves. These nerves are placed in the centre of regions in which the upper and lower limbs are developed. They are minute nerves, while the corresponding anterior primary divisions are among the largest of the spinal nerves. Thus, opposite the centre of each limb, posteriorly, there is a hiatus in the segmental distribution of the posterior primary divisions of the spinal nerves to the skin of the shoulder and buttock, attributable to the formation of the limbs, and the extension into them of the greater part of the nerves of the region. This gap, in the case of the upper limb, commences at the level of the vertebra prominens; in the case of the lower limb it commences opposite the level of the posterior superior iliac spine. It can be continued on to each limb as a hypothetical area (the **dorsal axial line**), which indicates the area of contact (and overlapping) of cutaneous nerves not in strictly numerical sequence. Thus, in the region of the shoulder, the sixth (or fifth) cervical nerve innervates an area of skin adjoining that supplied by the first thoracic nerve; in the region of the buttock the third lumbar nerve supplies an area contiguous with that supplied by the first sacral nerve.

B. The cutaneous branches of the posterior primary divisions of the spinal nerves differ from the muscular branches in respect of their penetration into regions beyond those supplied by their motor roots. The cutaneous branches, in regions where outgrowths or extensions from the trunk have occurred, follow these extensions; and, in consequence, supply skin covering parts which do not belong to segments represented by the nerves in question. Thus the second and third cervical nerves (great and least occipital) are drawn upwards so as to supply the posterior part of the *scalp*; the upper thoracic nerves are drawn outwards over the *scapular region*; the upper lumbar and sacral nerves supply the skin of the *buttock*; and the sacro-coccygeal nerve forms a rudimentary *caudal nerve*.

3. **Plexuses.**—The plexuses formed by the posterior primary divisions of the upper cervical and upper sacral nerves are the simplest met with in the human body. The posterior cervical plexus is one from which muscular branches are supplied; the posterior sacral plexus is mainly concerned in producing cutaneous offsets. In the case of the **posterior cervical plexus** the loops of communication between the first three or four cervical nerves result in the formation of a series of nerves for the supply of the semispinalis, complexus, and other muscles, which bring into contact with these muscles, simultaneously, a considerable area of the spinal cord, and provide a combined and simultaneous innervation for the several parts of each muscle. In the case of the **posterior sacral plexus**, the formation of loops between the nerves results in the innervation of any given spot in the cutaneous area supplied from these loops by more than one spinal nerve. As has been said already, the cutaneous nerves, even without the formation of plexuses, overlap in their cutaneous distribution. The formation of a plexus causes a more intimate union of neighbouring spinal nerves, so that stimulation of the surface affects a wider area in the spinal cord than if the nerves passed separately to it from the surface. While segmentation becomes less obvious, increased co-ordination is effected both of movement and sensation.

ANTERIOR PRIMARY DIVISIONS OF THE SPINAL NERVES.

The anterior primary divisions of the spinal nerves, are, with the exception of the first two cervical nerves, much larger than the corresponding posterior primary divisions. Composed of elements of both dorsal and ventral roots, each nerve separates from the posterior primary division on emerging from the intervertebral foramen, and, proceeding outwards, is distributed to structures on the lateral and anterior aspects of the body,—including the limbs.

Each nerve is joined near its origin by a **gray ramus communicans** from the sympathetic gangliated cord; and in the case of certain thoracic, lumbar, and sacral nerves, the anterior primary division gives off a delicate bundle of fibres, which forms the **white ramus communicans** of the sympathetic cord. That part of the spinal nerve which is distributed to the body wall and limbs may be termed **somatic**; the small white ramus communicans, innervating the structures in the splanchnic area, may be termed the **visceral** or **splanchnic** part of the spinal nerve.

The anterior primary divisions of the spinal nerves are only,

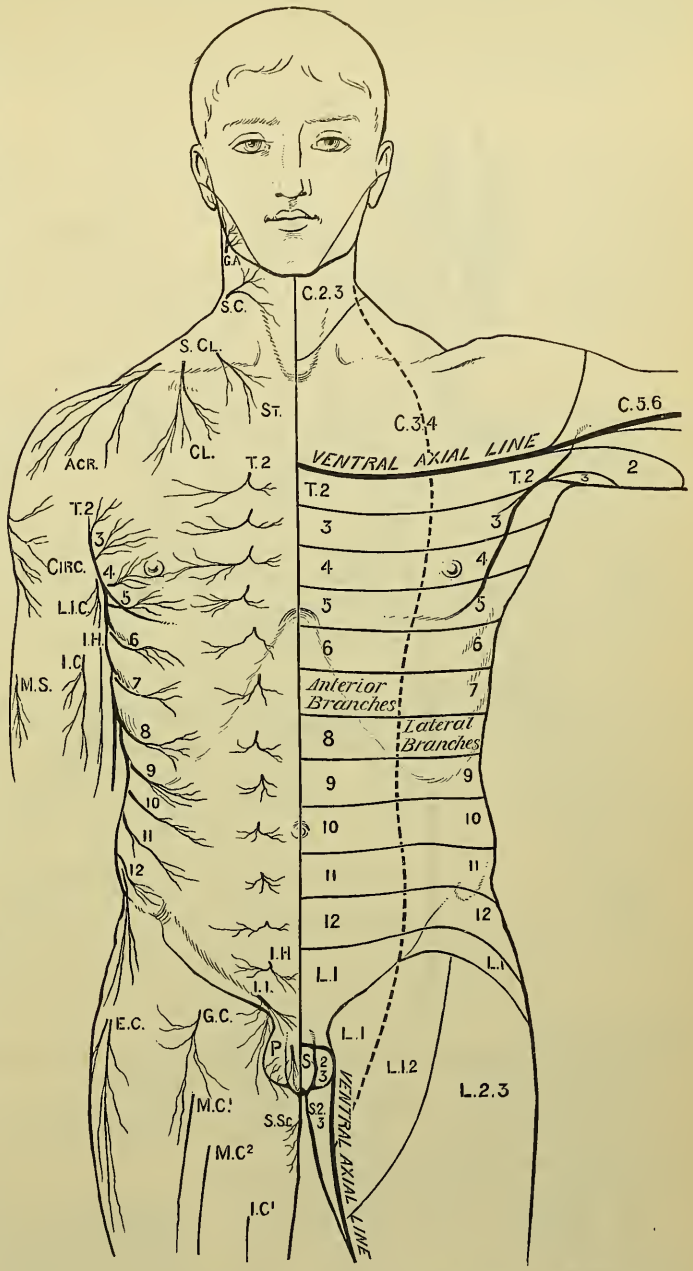


FIG. 489.—THE DISTRIBUTION OF CUTANEOUS NERVES ON THE FRONT OF THE TRUNK.

On one side the distribution of the several nerves is represented, the letters indicating their nomenclature.

G.A, Great auricular nerve; S.C, Superficial cervical nerve; S.CL, Supra-clavicular nerves; ACR, Acromial; CL, Clavicular; ST, Sternal; T.2-12, Lateral and anterior branches of thoracic nerves; I.H, Ilio-hypogastric nerve; I.I, Ilio-inguinal nerve; CIRC, Cutaneous branch of circumflex nerve; L.I.C, Lesser internal cutaneous nerve; I.H, Intercosto-humeral; I.C, Internal cutaneous; M.S, Cutaneous branch of musculo-spiral nerve; E.C, External cutaneous nerves; G.C, Genito-crural nerve; M,C¹ ², Middle cutaneous nerves; I.C¹, Branch of internal cutaneous nerve; P, Branches of pudic nerve; S.Sc, Branches of small sciatic nerve.

On the other side a schematic representation is given of the areas supplied by the above nerves, the numerals indicating the spinal origin of the branches of distribution to each area.

in certain cases, distributed in a regular segmental manner. Except in the case of the thoracic nerves, the anterior primary divisions combine to form the three great **plexuses**—cervical, brachial, and lumbo-sacral—and their arrangement and distribution is rendered exceedingly complex.

A **thoracic nerve**, such as the fifth or sixth, may be regarded as a type to illustrate the mode of distribution of the anterior primary divisions of the spinal nerves (Fig. 486, p. 609). It occupies an intercostal space; near its origin it possesses *gray* and *white rami communicantes*; it courses through the interval between the intercostal muscles; it supplies branches to these muscles and gives off, when it reaches the side of the chest, a *lateral branch*, which, after supplying small muscular branches, pierces the external intercostal muscle, and is distributed to an area of skin over the lateral part of the trunk, contiguous dorsally with a similar area, innervated by the cutaneous branches of the posterior primary division of the same nerve. The lateral branch generally subdivides into a smaller *posterior* and a larger *anterior trunk*, as it pierces the muscles clothing the wall of the chest. The anterior primary division of the nerve then pursues its course obliquely forwards to the side of the sternum, where, after piercing the pectoral muscles, it appears superficially as the *anterior terminal cutaneous branch*. This supplies an area of skin continuous with that supplied by the anterior part of the lateral branch of the same nerve. Such a nerve thus supplies, by means of its lateral and anterior

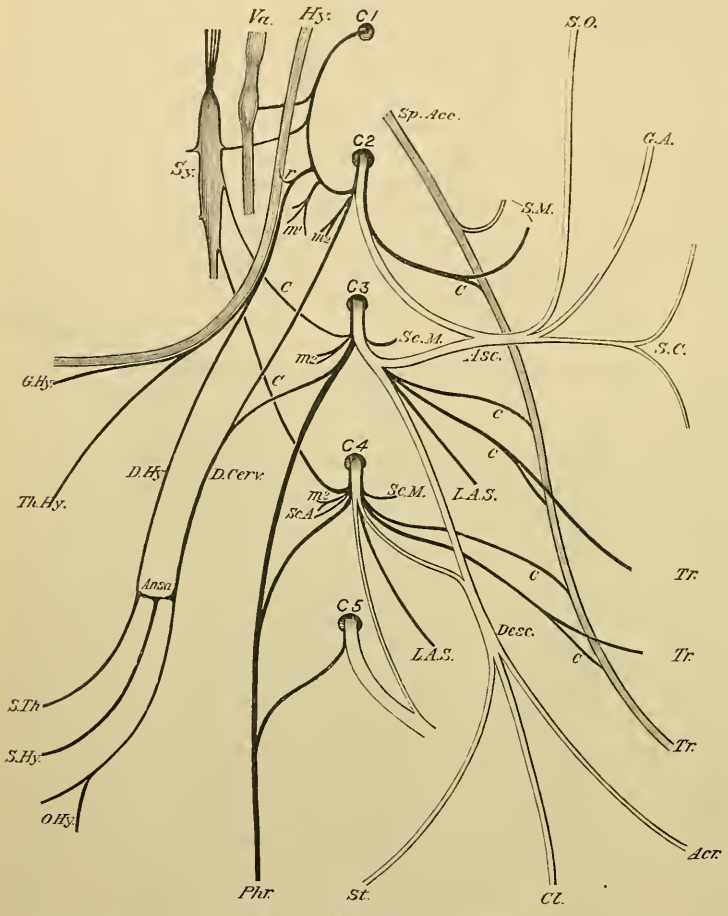


FIG. 490.—THE CERVICAL PLEXUS.

Superficial Division.

Ascending branches (Asc.)—
- S.O. Small occipital.
- G.A. Great auricular.
- S.C. Superficial cervical.

Descending (supra-clavicular) branches (Desc.)—
- Acr. Acromial.
- Cl. Clavicular.
- St. Sternal.

Deep Division.

External branches—
Communicating (C.) to spinal accessory nerve (Sp. Acc.).
Muscular—
- S.M. Sterno-mastoid.
- Tr. Trapezius.
- L.A.S. Levator anguli scapulæ.
- Sc.M. Scalenus medius.

Internal branches—
Communicating to
- Hy. Hypoglossal.
- Va. Vagus.
- Sy. Sympathetic ganglion.
- D.Cerv. Descendens cervicis.

Muscular—
- M^1. Rectus capitis anticus minor, and lateralis.
- M^2. Longus colli, and rectus capitis anticus major.
- Sc.A. Scalenus anticus.
- Phr. Phrenic nerve.
- G.Hy. Nerve to genio-hyoid.
- Th.Hy. Nerve to thyro-hyoid.
- D.Hy. Descendens hypoglossi.
- Ansa. Ansa hypoglossi.
- S.Th. Nerve to sterno-thyroid.
- S.Hy. Nerve to sterno-hyoid.
- O.Hy. Nerves to omo-hyoid.

branches, an area of skin which (with the area supplied by the cutaneous branch of its posterior primary division) forms a continuous and uninterrupted belt, extending from the middle line behind to the middle line in front. The lateral and anterior branches of the nerve innervate in their course the intercostal and other muscles, to be afterwards mentioned in detail.

CERVICAL NERVES.

The anterior primary divisions of the cervical nerves, together with parts of the first and second thoracic nerves, are distributed to the head, neck, and upper extremity. The first four cervical nerves, by means of the **cervical plexus**, innervate the neck; the last four cervical nerves, together with a large part of the first thoracic nerve, through the **brachial plexus**, supply the upper limb. The second thoracic nerve may contribute a trunk to this plexus, and always assists in the innervation of the arm.

THE CERVICAL PLEXUS.

The anterior primary divisions of the first four cervical nerves are concerned in forming the cervical plexus. Each nerve emerges from the spinal canal behind the vertebral artery. Each is joined on its emergence from the intervertebral foramen, at the side of the vertebral column, by a **gray ramus communicans** from the superior cervical ganglion of the sympathetic. In the neck the cervical nerves are concealed by the sterno-mastoid muscle; in front lies the rectus capitis anticus major, and behind are the scalenus medius, and (behind the first or sub-occipital nerve) the rectus capitis lateralis. The cervical plexus is constituted by the combination of these nerves in an irregular series of loops under cover of the sterno-mastoid muscle.

From these loops the branches of distribution arise, as (*a*) **cutaneous branches** to the head, neck, and shoulder; (*b*) **muscular branches** to the muscles of the neck and the diaphragm; and (*c*) **communicating branches** to the vagus, spinal accessory, hypoglossal, and sympathetic nerves.

For convenience of description, the nerves derived from the plexus may be classified as follows:—

I. Superficial (cutaneous) Branches—

A. **Ascending Branches** (C. 2, 3).
- Small occipital,
- Great auricular,
- Superficial cervical.

B. **Descending (supra-clavicular) Branches** (C. 3, 4).
- Acromial,
- Clavicular,
- Sternal.

II. Deep (muscular and communicating) Branches—

A. **External Branches.**

1. Muscular branches to
   - Sterno-mastoid (C. 2),
   - Trapezius (C. 3, 4),
   - Levator anguli scapulæ (C. 3, 4),
   - Scaleni (medius and posticus) (C. 3, 4).
2. Communicating branches to
   - Spinal accessory nerve (C. 2, 3, 4).

B. **Internal Branches.**

1. Muscular to
   - Prevertebral muscles (C. 1, 2, 3, 4),
   - Infra-hyoid muscles (C. 1, 2, 3) (ansa hypoglossi),
   - Diaphragm (C. 3, 4) (phrenic nerve).
2. Communicating branches to
   - Vagus nerve (C. 1, 2),
   - Hypoglossal nerve (C. 1, 2),
   - C. Hypoglossi (C. 2, 3),
   - Sympathetic (C. 1, 2, 3, 4).

The second, third, and fourth cervical nerves are the chief nerves engaged in forming the plexus. The first cervical nerve only enters into the formation of a small part—the internal portion of the deep part of the plexus.

Superficial Cutaneous Branches.—These nerves, six in number, are entirely cutaneous. They radiate from the plexus, and appear in the posterior triangle of

the neck at the posterior border of the sterno-mastoid muscle. They are divisible into two series, the one **ascending**: small occipital, great auricular, and superficial cervical; the other **descending** (supra-clavicular): sternal, clavicular, and acromial.

Ascending Branches.—The **small occipital nerve** (n. occipitalis minor) is variable in size and is sometimes double. Its origin is from the second and third cervical nerves (more rarely from the second only). It extends backwards beneath the sterno-mastoid, and then upwards along its posterior border. Piercing the deep fascia near the apex of the posterior triangle, it divides into **auricular, mastoid,** and **occipital branches,** and supplies small **cervical branches** to the upper part of the neck. The auricular branch supplies the skin of the deep surface of the pinna; the mastoid and occipital branches supply the scalp. The nerve communicates on the scalp with the great occipital and great auricular nerves, and with the posterior auricular branch of the facial nerve.

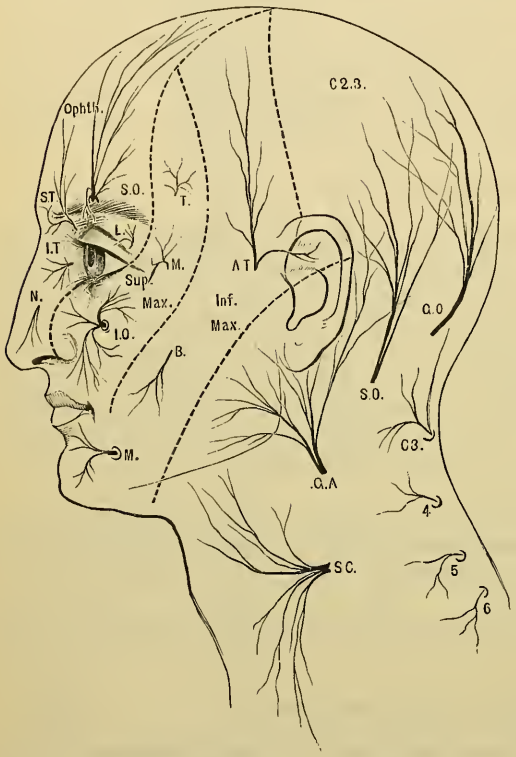


FIG. 491.—DISTRIBUTION OF CUTANEOUS NERVES TO THE HEAD AND NECK.

Ophth, Ophthalmic division of the fifth nerve; S.T, Supra-trochlear branch; S.O, Supra-orbital branch; I.T, Infra-trochlear branch; L, Lachrymal branch; N, External nasal branch; Sup.Max, Superior maxillary division; T, Temporal branch; M, Malar branch; I.O, Infra-orbital branch; Inf.Max, Inferior maxillary division; A.T, Auriculo-temporal branch; B, Buccal branch; M, Mental branch; C.2, 3, Branches of the second and third cervical nerves; G.O, Great occipital nerve; S.O, Small occipital nerve; G.A, Great auricular nerve; S.C, Superficial cervical nerve; C.3, Least occipital nerve; 4, 5, 6, Posterior primary divisions of 4th, 5th, and 6th cervical nerves.

The **great auricular nerve** (n. auricularis magnus) is the largest of the cutaneous branches. It arises from the second and third cervical nerves (or, more rarely, from the third alone). Winding round the posterior border of the sterno-mastoid muscle, it courses vertically upwards towards the ear. In this course it crosses the sterno-mastoid muscle obliquely and is covered by the platysma myoides. Before arriving at the ear it subdivides into mastoid, auricular, and facial branches. The **mastoid branches** ascend over the mastoid process and supply the skin of the scalp behind the ear, communicating with the small occipital and posterior auricular nerves. The **auricular branches** ascend to the ear and supply the lower part of the pinna on both aspects; they communicate with the same nerves. The **facial branches,** passing over the angle of the jaw and through the substance of the parotid gland, supply the skin of the cheek over the lower part of the masseter muscle and the parotid gland. They communicate with branches of the facial nerve in the parotid gland.

The **superficial cervical nerve** (n. cutaneus colli) arises from the second and third cervical nerves. It winds round the posterior border of the sterno-mastoid muscle, and crosses the muscle to reach the anterior triangle, under cover of the platysma myoides muscle and the external jugular vein. It divides near the anterior edge of the sterno-mastoid muscle into upper and lower branches, which are distributed through the platysma myoides to the skin covering the anterior triangle of the neck. The upper branches communicate freely beneath the platysma myoides with the infra-mandibular branch of the facial nerve.

Descending (supra-clavicular) Branches.—By the union of two roots derived from the third and fourth cervical nerves a considerable trunk is formed, which

emerges from under cover of the sterno-mastoid muscle and extends obliquely downwards through the lower part of the posterior triangle of the neck. It subdivides into radiating branches—**sternal, clavicular,** and **acromial**—which pierce the deep fascia of the neck above the clavicle, and are distributed to the skin of the lower part of the side of the neck, the front of the chest, and the shoulder. The **sternal branches** (rami supra-sternales) are the smallest. Passing over the inner end of the clavicle, they supply the skin of the neck and chest as far down as the manubrio-sternal joint. The **clavicular branches** (rr. supra-claviculares) pass over the middle third of the clavicle, beneath the platysma, and can be traced

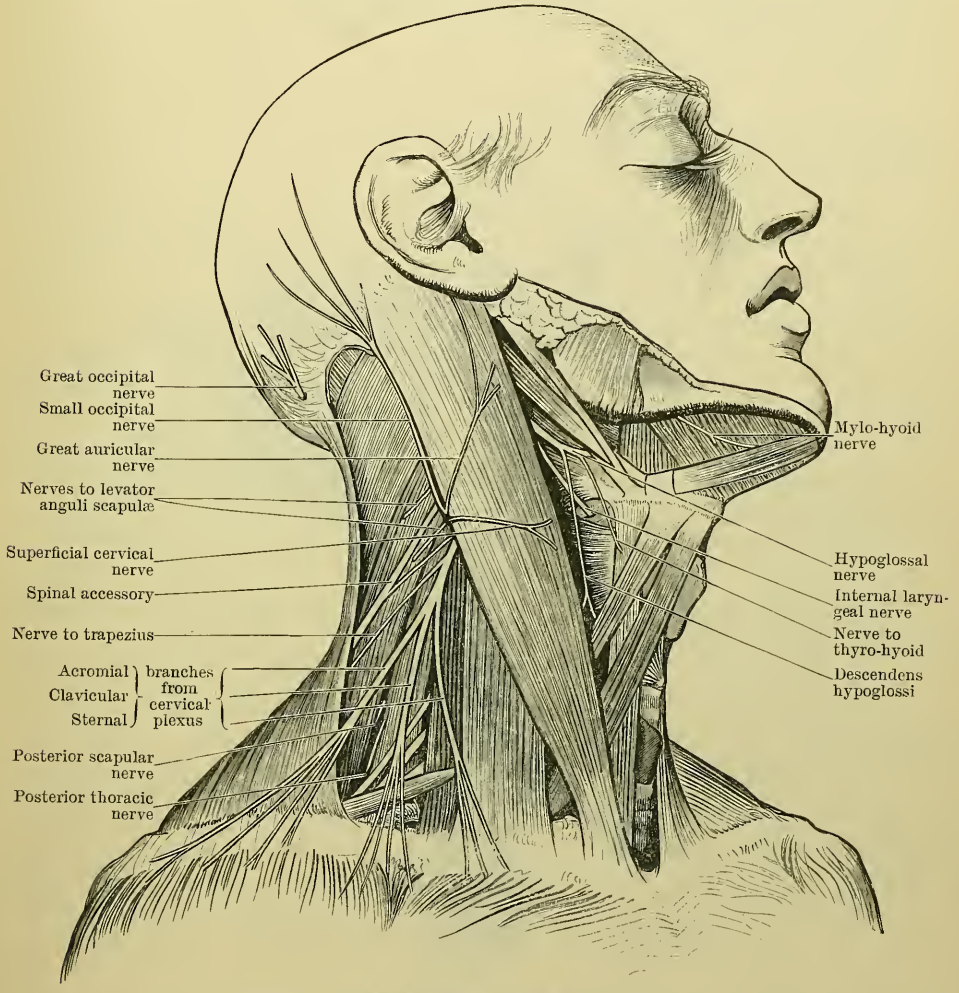


FIG. 492.—THE TRIANGLES OF THE NECK (Nerves).

as low as the nipple. The **acromial branches** (rr. supra-acromiales) pass over or through the insertion of the trapezius muscle, and over the outer third of the clavicle, to the shoulder, where they supply the skin as far down as the lower third of the deltoid muscle.

Deep Branches.—The deep branches of the cervical plexus are naturally separated into an **external** and an **internal set** by their relation to the sterno-mastoid muscle. Beneath the muscle, the external branches are directed outwards towards the posterior triangle, the internal branches inwards towards the anterior triangle.

The **external branches** consist of muscular and communicating nerves, which for the most part occupy the posterior triangle.

The **muscular branches** are the following: (1) To the *sterno-mastoid*, from the second cervical nerve. This enters the muscle on its deep surface and communicates

with the spinal accessory nerve. (2) To the *trapezius*, from the third and fourth cervical nerves. These nerves cross the posterior triangle and end in the trapezius, after having communicated with the spinal accessory nerve, in the posterior triangle, and beneath the muscle. (3) To the *levator anguli scapulæ*, from the third and fourth cervical nerves. Two independent branches enter the outer surface of the muscle in the posterior triangle. (4) To the *scaleni* (medius and posticus), from the third and fourth cervical nerves.

The **communicating branches**, already mentioned, are three in number. They

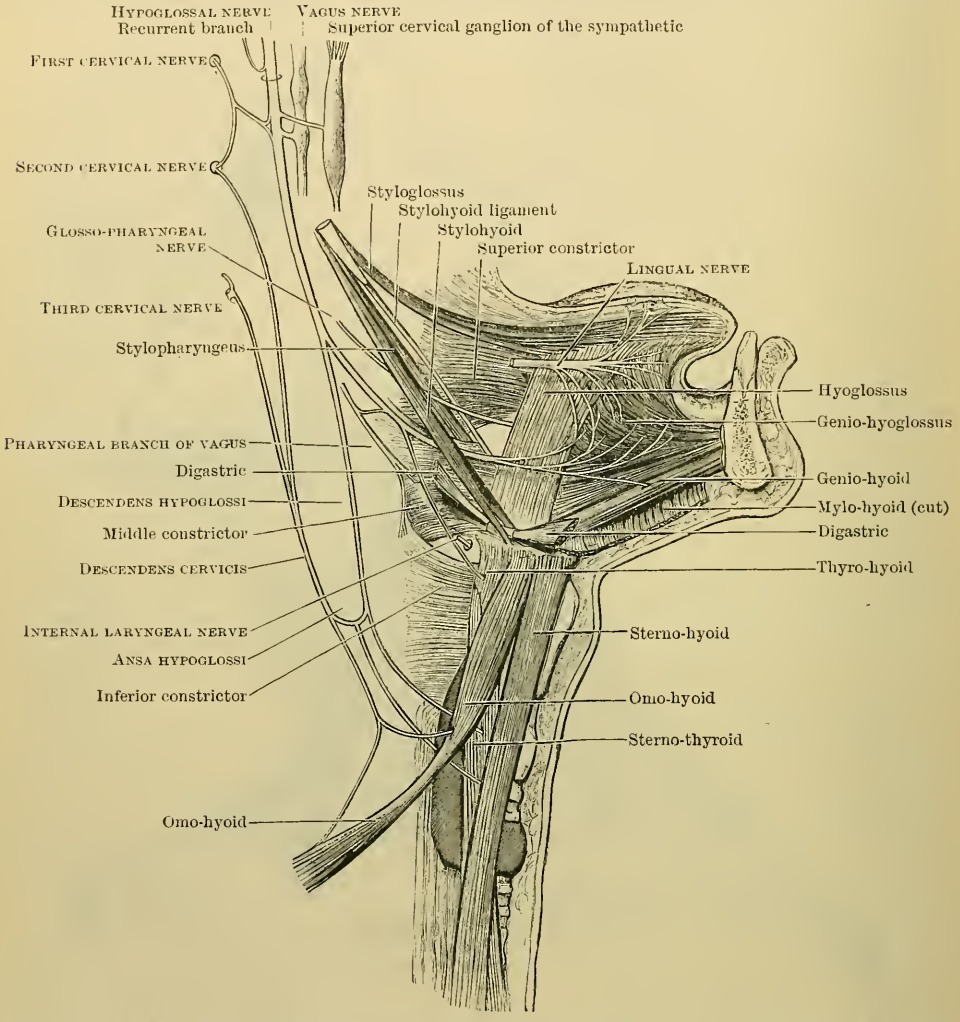


Fig. 493.—The Muscles of the Hyoid Bone and Styloid Process, and the Extrinsic Muscles of the Tongue, with their Nerves.

join the spinal accessory nerve in three situations:—(*a*) A branch from the second cervical nerve to the sterno-mastoid joins the spinal accessory nerve *beneath that muscle*. (*b*) Branches to the trapezius from the third and fourth nerves are connected with the spinal accessory nerve *in the posterior triangle*. (*c*) Branches from the same nerves join the spinal accessory nerve *beneath the trapezius muscle*.

The **internal branches** of the plexus also comprise muscular and communicating branches. The first cervical nerve assists in the formation of this series of nerves, forming a slender loop with part of the second nerve in front of the transverse process of the atlas.

Communicating Branches. (*a*) *With the sympathetic.*—Gray rami communicantes pass to each of the first four cervical nerves, near their origins, from the

superior cervical ganglion or from the cord below the ganglion. (*b*) *With the pneumogastric nerve.*—The ganglion of the trunk of the pneumogastric nerve may be connected by a slender nerve with the loop between the first two cervical nerves. This communication is not constant. (*c*) *With the hypoglossal.*—An important communication occurs between the hypoglossal nerve and the loop between the first and second cervical nerves (Fig. 493). A trunk from the last-named nerves joins the hypoglossal just beyond its exit from the skull. One fine branch from this trunk passes upwards along the hypoglossal nerve towards the skull (*meningeal branch*). The main part of the trunk accompanies the hypoglossal and separates from it successively in three nerves—the **descendens hypoglossi**, and the **nerves to the thyro-hyoid** and **genio-hyoid muscles.** The portion of the nerve which remains accompanies the hypoglossal to the muscles of the tongue. It is probable that no part of the hypoglossal nerve itself is concerned in the formation of these three branches. The descending branch of the hypoglossal (r. descendens hypoglossi) descends in front of the common carotid artery, and is joined in the anterior triangle of the neck by the descending cervical nerve, to form the ansa hypoglossi, from which the infra-hyoid muscles are innervated. (The descending branch of the hypoglossal, in some cases, arises from the pneumogastric nerve.)

Muscular Branches.—The muscles supplied by the internal branches of the plexus are the prevertebral muscles, the genio-hyoid and infra-hyoid muscles, and the diaphragm.

(*a*) **Prevertebral Muscles.**—1. From the loop between the first and second cervical nerves a small branch arises, for the supply of the rectus capitis lateralis and the recti capitis antici (major and minor). 2. From the second, third, and fourth nerves small branches supply the inter-transversales, longus colli, and rectus capitis anticus major. 3. From the fourth nerve a branch arises for the upper part of the scalenus anticus.

(*b*) **Genio-hyoid and Infra-hyoid Muscles.**—The **descending cervical nerve** (n. cervicalis descendens) is formed in front of the internal jugular vein by the union of two slender trunks from the second and third cervical nerves. It forms a loop of communication in front of the carotid sheath with the descending branch of the hypoglossal nerve (derived ultimately from the first two cervical nerves). This loop of communication is called the **ansa hypoglossi.** It is often plexiform; and from it branches are given to the sterno-hyoid, sterno-thyroid, and omo-hyoid muscles. The nerve to the sterno-hyoid muscle is often continued behind the sternum, to join in the thorax with the phrenic nerve or the cardiac plexus.

The thyro-hyoid muscle and the genio-hyoid muscle are supplied by branches of the hypoglossal nerve, which are also traceable back to the communication between the hypoglossal and the first two cervical nerves.

The anterior muscles in immediate relation to the middle line of the neck, between the chin and the sternum, are thus continuously supplied by the first three cervical nerves. The hypoglossal is the nerve of the muscles of the tongue, and it is not certain that it contributes any fibres to the above-named muscles.

(*c*) **Diaphragm.**—The phrenic nerve supplies the diaphragm.

Phrenic Nerve.

The **phrenic nerve** (n. phrenicus) is derived mainly from the fourth cervical nerve, reinforced by roots from the third (either directly or through the nerve to the sterno-hyoid) and fifth (either directly or through the nerve to the subclavius muscle). It passes downwards in the neck upon the scalenus anticus muscle; at the root of the neck it enters the thorax between the subclavian artery and vein, and traverses the mediastinum to reach the diaphragm, lying in the middle mediastinum between the pericardium and pleura, and in front of the root of the lung. In its course it presents certain differences on the two sides. In the neck, on the left side, it crosses the first part of the subclavian artery: on the right side it crosses the second part. In the superior mediastinum, *on the left side,* it lies between the left subclavian and carotid arteries, and crosses the pneumogastric nerve and the aortic arch. *On the right side* it accompanies the innominate vein

and superior vena cava, and is entirely separate from the pneumogastric nerve. The left nerve is longer than the right, owing to the position of the heart and the left half of the diaphragm. The right nerve sends fibres along the inferior vena cava through the foramen quadratum. Reaching the diaphragm the nerve separates into numerous branches for the supply of the muscle; some enter its thoracic surface (sub-pleural branches), but most of the fibres supply it after piercing the muscle (sub-peritoneal branches).

The **branches of the phrenic nerve** are—1. Muscular (to the diaphragm); 2. pleural; 3. pericardiac; 4. inferior vena caval; 5. capsular; and 6. hepatic.

The branches to the pleura and pericardium arise as the phrenic nerve traverses the mediastinum. The branches to the inferior vena cava, suprarenal capsule, and liver arise after communication of the phrenic nerve with the diaphragmatic plexus of the sympathetic on the abdominal surface of the diaphragm.

Communications of the Phrenic Nerve.—1. The phrenic nerve may communicate with the nerve to the subclavius muscle. 2. It may communicate with the *ansa hypoglossi*, or a branch from it (the nerve to the sterno-hyoid). 3. It frequently communicates with the cervical part of the sympathetic. 4. It communicates with the solar plexus by a junction upon the abdominal surface of the diaphragm with the *diaphragmatic plexus* on the inferior phrenic artery, in which a small *diaphragmatic ganglion* is found on the right side. From this junction branches are given off to the inferior vena cava, suprarenal capsule, and hepatic plexus.

Morphology of the Cervical Plexus.

The characteristic feature of the cervical plexus is the combination of parts of adjacent nerves into compound nerve-trunks by the formation of series of loops. The result of the formation of these loops is that parts (particularly cutaneous areas) are supplied by branches of more than one spinal nerve.

A. **Cutaneous Distribution.**—By the combinations of the nerves into loops the discrimination of the elements in the upper cervical nerves, corresponding to the lateral and anterior branches of a typical thoracic nerve, is made a matter of some difficulty. The second, third, and fourth nerves, through the cervical plexus, supply an area of skin extending, laterally, from the side of the head to the shoulder; anteriorly, from the face to the level of the nipple. The higher nerves supply the upper region (second and third); the lower nerves supply the lower region (third and fourth). It is not possible to strictly compare the individual nerves with the lateral and anterior branches of a thoracic nerve. A line drawn from the ear to the middle of the clavicle separates, however, a lateral from an anterior cutaneous area; and certain of the cutaneous nerves fall naturally into one of these two categories. The nerves homologous with anterior branches of intercostal nerves are the superficial cervical and the sternal branches of the supra-clavicular series; those homologous with lateral branches are the small occipital and acromial branches. The great auricular and clavicular branches are mixed nerves, comprising elements belonging to both sets.

B. **Muscular Distribution.**—The nerves from the cervical plexus, supplying muscles, are simpler in their arrangement. They are not generally in the form of loops, and they are easily separated into lateral and anterior series. The lateral nerves comprise the branches to the rectus capitis lateralis, sterno-mastoid, trapezius, levator anguli scapulæ. The nerves in the anterior series are those to the recti antici, the hyoid muscles, and the diaphragm.

It is noteworthy that the last-named muscles—genio-hyoid, thyro-hyoid, sterno-hyoid, omo-hyoid, sterno-thyroid, and diaphragm—are continuously supplied by branches from the first five cervical nerves: the higher muscles by the higher nerves; the lower muscles by the lower nerves.

THE BRACHIAL PLEXUS.

The brachial plexus is formed by the anterior primary divisions of the fifth, sixth, seventh, and eighth cervical nerves, along with the greater part of the first thoracic nerve. In some cases a slender branch of the fourth cervical nerve is also engaged; and the second thoracic nerve, in all cases, also contributes to the innervation of the arm, through the intercosto-humeral nerve. It many cases it contributes also directly to the plexus, by an intra-thoracic communication with the first thoracic nerve.

Position of the Plexus—The nerves forming the brachial plexus appear in the posterior triangle of the neck between the scalenus anticus aud scalenus

medius muscles; the plexus is formed in close relation to the subclavian and axillary arteries; the nerves emanating from it accompany the artery to the axilla, where they are distributed to the shoulder and upper limb.

Communication with the Sympathetic.—The lower four cervical nerves communicate with the cervical portion of the sympathetic by means of **gray rami communicantes.** Two branches arise from the middle cervical ganglion, and join the anterior primary divisions of the fifth and sixth nerves. Two arising from the inferior cervical ganglion join the seventh and eighth nerves. They reach the nerves either by piercing the prevertebral muscles or by passing round the border of the scalenus anticus muscle.

Composition of the Brachial Plexus.—In an analysis of the brachial plexus four stages may be always seen:—

(1) The undivided nerves.

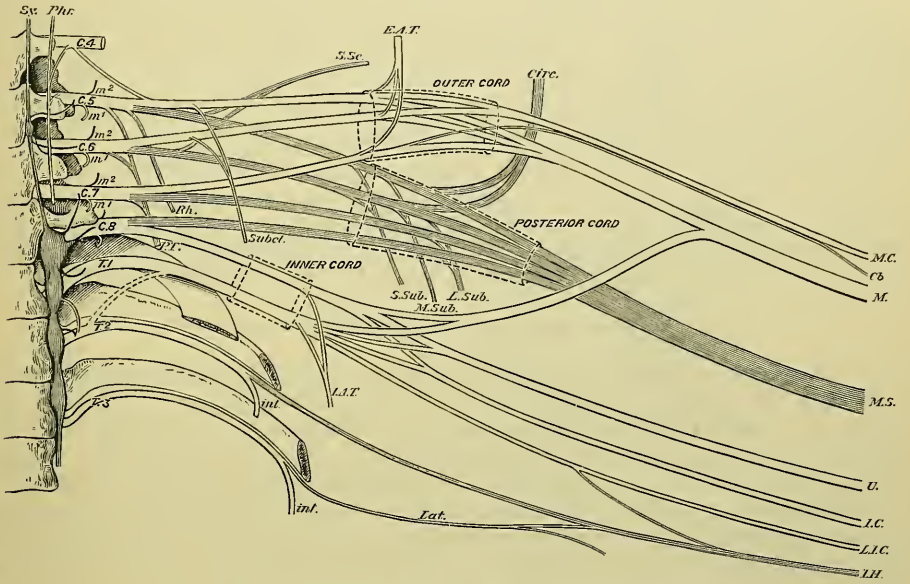


Fig. 494.—The Nerves of the Brachial Plexus.

Sy, Sympathetic gangliated cord; Phr, Phrenic nerve; C.4, 5, 6, 7, 8, T.1, 2, 3, Anterior primary divisions of the lower cervical and upper thoracic nerves; M^1, M^2, Muscular branches to axial muscles; P.T, Long thoracic nerve; Rh, Nerve to rhomboids (posterior scapular); Subcl, Nerve to subclavius muscle; Int, Intercostal nerves; S.Sc, Supra-scapular nerve. The intercostal part of the first thoracic nerve is omitted.

Outer Cord.—E.A.T, External anterior thoracic nerve; M.C, Musculo-cutaneous nerve; Cb, Nerve to coraco-brachialis; M, Median nerve.

Inner Cord.—I.A.T, Internal anterior thoracic nerve; U, Ulnar nerve; I.C, Internal cutaneous nerve; L.I.C, Lesser internal cutaneous nerve.

Posterior Cord.—Circ, Circumflex nerve; M.S, Musculo-spiral nerve; S.Sub, Short subscapular nerve; M.Sub, Lower subscapular nerve; L.Sub, Long subscapular, nerve; I.H, Intercosto-humeral nerve; Lat, Lateral branch of third intercostal nerve.

(2) The separation of the nerves into ventral (anterior) and dorsal (posterior) trunks; and the formation of three primary cords.

(3) The formation of three secondary cords—outer, inner, and posterior.

(4) The origin of the nerves of distribution.

(1) The undivided nerves have only a very short independent course at the side of the neck, after passing between the scalene muscles.

(2) Almost immediately after entering the posterior triangle there are formed three **primary cords**: the first cord is formed by the union of the fifth and sixth nerves together; the second, by the seventh nerve alone; and the third, by the union of the eighth cervical and first thoracic nerves together. While these cords are being formed, a division occurs in each of the last four cervical nerves, into *ventral* (anterior) and *dorsal* (posterior) *trunks*; the first thoracic nerve usually gives rise to no dorsal trunk. The ventral and dorsal trunks of the fifth, sixth,

and seventh nerves are nearly equal in size. The dorsal trunk of the eighth cervical nerve is much smaller.

(3) The **secondary cords** of the plexus are formed by combinations of these ventral and dorsal trunks in relation to the axillary artery. They are three in number. The **outer cord** (fasciculus lateralis) is formed by a combination of the ventral trunks of the fifth, sixth, and seventh nerves, and lies on the outer side of the axillary artery. The **inner cord** (fasciculus medialis) is formed by a combination of the ventral trunk of the eighth cervical with the part of the first thoracic nerve engaged in the formation of the plexus; it lies on the inner side of the axillary artery. The **posterior cord** (fasciculus posterior) is made up of all the dorsal trunks from the fifth, sixth, seventh, and eighth cervical nerves, and lies behind the axillary artery. The first thoracic nerve does not usually contribute to the posterior cord, and the branch when present is a fine nerve.

(4) The **nerves of distribution** for the shoulder and arm are derived from these secondary cords, and receive in this way various contributions from the constituent spinal nerves. *From the outer cord* arise the external anterior thoracic and musculo-cutaneous nerves, and the outer head of the median nerve. *From the inner cord* arise the inner head of the median, the ulnar, internal cutaneous, lesser internal cutaneous, and the internal anterior thoracic nerves. *From the posterior cord* arise the circumflex, the three subscapular, and the musculo-spiral nerves.

It is to be remembered that, although derived from a secondary cord formed by a certain set of spinal nerves, any given nerve does not necessarily contain fibres from all the constituent nerves; *e.g.* both the musculo-cutaneous and circumflex nerves, from the outer and posterior cords respectively, are ultimately derived only from the fifth and sixth cervical nerves.

The Branches of the Brachial Plexus.

It is customary to separate artificially the nerves of distribution of the brachial plexus into two sets: (1) supra-clavicular and (2) infra-clavicular. Clinically it is important to realise the position of origin of certain nerves. The nerves to the prevertebral muscles, the communication with the phrenic, the posterior scapular, and long thoracic nerves, arise from the *roots* of the nerves involved in the plexus. The supra-scapular and the nerve to the subclavius arise at the level of formation of the secondary cords; and the anterior thoracic and subscapular nerves arise from the secondary cords, prior to their ultimate subdivision into the nerves of distribution for the upper limb.

Supra-clavicular Nerves.—The nerves derived from the plexus above the level of the clavicle are, like the main trunks, divisible into two series; **anterior branches** arising from the front, and **posterior branches** arising from the back of the plexus (Fig. 494, p. 623).

Anterior Branches.	Posterior Branches.
1. Nerves to scalenus anticus and longus colli.	1. Nerves to scaleni, medius and posticus.
2. Communicating nerve to join the phrenic nerve.	2. Posterior scapular nerve.
3. Nerve to the subclavius muscle.	3. Long thoracic nerve.
	4. Supra-scapular nerve.

The **muscular twigs** to the scalenus anticus and longus colli arise from the lower four cervical nerves, as they emerge from the intervertebral foramina.

The **communicating nerve to the phrenic** arises usually from the fifth cervical nerve at the outer border of the scalenus anticus. It is sometimes absent, and occasionally an additional root is present from the sixth cervical nerve. In some instances the nerve is replaced by a branch from the nerve to the subclavius, which passes inwards behind the sterno-mastoid muscle to join the phrenic at the inlet of the thorax.

The **nerve to the subclavius** is a slender nerve, which arises from the front of the cord formed by the fifth and sixth cervical nerves. It descends in the posterior triangle of the neck over the third part of the subclavian artery. It often communicates with the phrenic nerve.

The **branches to the scaleni, medius and posticus**, are small trunks which arise from the lower four cervical nerves as they emerge from the intervertebral foramina.

The **posterior scapular nerve** (n. dorsalis scapulæ, nerve to the rhomboids) arises from the back of the fifth cervical nerve, as it emerges from the intervertebral foramen. It appears in the posterior triangle of the neck, after piercing the scalenus medius muscle. It is directed downwards, under cover of the levator anguli scapulæ and rhomboid muscles, and along the vertebral border of the scapula, to be distributed to the levator anguli scapulæ, rhomboideus minor, and rhomboideus major muscles. It occasionally pierces the levator anguli scapulæ.

The **long thoracic nerve** (n. thoracalis longus, external respiratory nerve of Bell) arises by three roots, of which the middle one is usually the largest, from the back of the fifth, sixth, and seventh nerves, as they emerge from the intervertebral foramina. The nerve pierces the scalenus medius as two trunks, of which the lower represents the contribution from the seventh cervical nerve, and, descending along the side of the neck behind the cords of the brachial plexus, it enters the axilla between the upper edge of the serratus magnus and the axillary artery. It continues its downward course over the outer surface of the serratus magnus, to which it is distributed.

There is a more or less definite relation between the roots of this nerve and the parts of the serratus magnus. The first part of the muscle is innervated by the fifth nerve alone; the second part by the fifth and sixth, or the sixth alone; the third part by the sixth and seventh, or the seventh nerve alone.

The **suprascapular nerve** (n. suprascapularis) arises from the back of the cord formed by the fifth and sixth cervical nerves in the posterior triangle of the neck. It occupies a position above the main cords of the brachial plexus, and courses downwards and outwards parallel to them towards the superior border of the scapula. It passes through the suprascapular foramen to reach the dorsum of the scapula. After supplying the supraspinatus muscle it winds round the great scapular notch in company with the suprascapular artery and terminates in the infraspinatus muscle. It also supplies articular branches to the back of the shoulder joint.

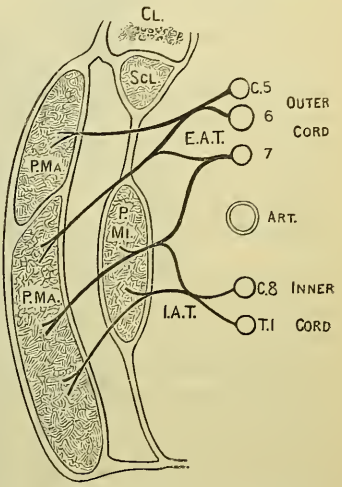


FIG. 495.—DIAGRAM OF THE ORIGIN AND DISTRIBUTION OF THE NERVES TO THE PECTORAL MUSCLES.

E.A.T, External anterior thoracic nerve; I.A.T, Internal anterior thoracic nerve; C.5, 6, 7, C.8, T.1, Nerves of the brachial plexus; ART, Axillary artery; CL, Clavicle; SCL, Subclavius muscle; P.MI, Pectoralis minor, joined to subclavius by costo-coracoid membrane; P.MA, Pectoralis major.

Infra-clavicular Nerves.—The so-called infra-clavicular branches of the brachial plexus are distributed to the chest, shoulder, and arm. According to their origin they are divisible into two sets—an **anterior set**, derived from the outer and inner cords, and a **posterior set**, derived from the posterior cord. In their distribution the same division is maintained. The anterior nerves of distribution, springing from the outer and inner cords, supply generally the chest and the front of the limb; the posterior nerves, springing from the posterior cord, supply the shoulder and the back of the limb.

Anterior Branches.

Nerves from the Outer Cord.

External anterior thoracic. Outer head of median. Musculo-cutaneous.

Nerves from the Inner Cord.

Internal anterior thoracic. Ulnar. Inner head of median.
Internal cutaneous. Lesser internal cutaneous.

Posterior Branches.

Nerves from the Posterior Cord.

Circumflex. Musculo-spiral. Three subscapular nerves.

Anterior Thoracic Nerves.

The **anterior thoracic nerves** (nn. thoracicales anteriores) are two in number, external and internal. The **external anterior thoracic nerve** arises from the outer cord of the brachial plexus by three roots—from the fifth, sixth, and seventh cervical nerves. The **internal anterior thoracic nerve** arises from the inner cord of the plexus, from the eighth cervical and first thoracic nerves. Each courses downwards and forwards on either side of the axillary artery. A loop of communication is formed between them over the artery. They are finally distributed to the pectoralis major and minor muscles (Fig. 495).

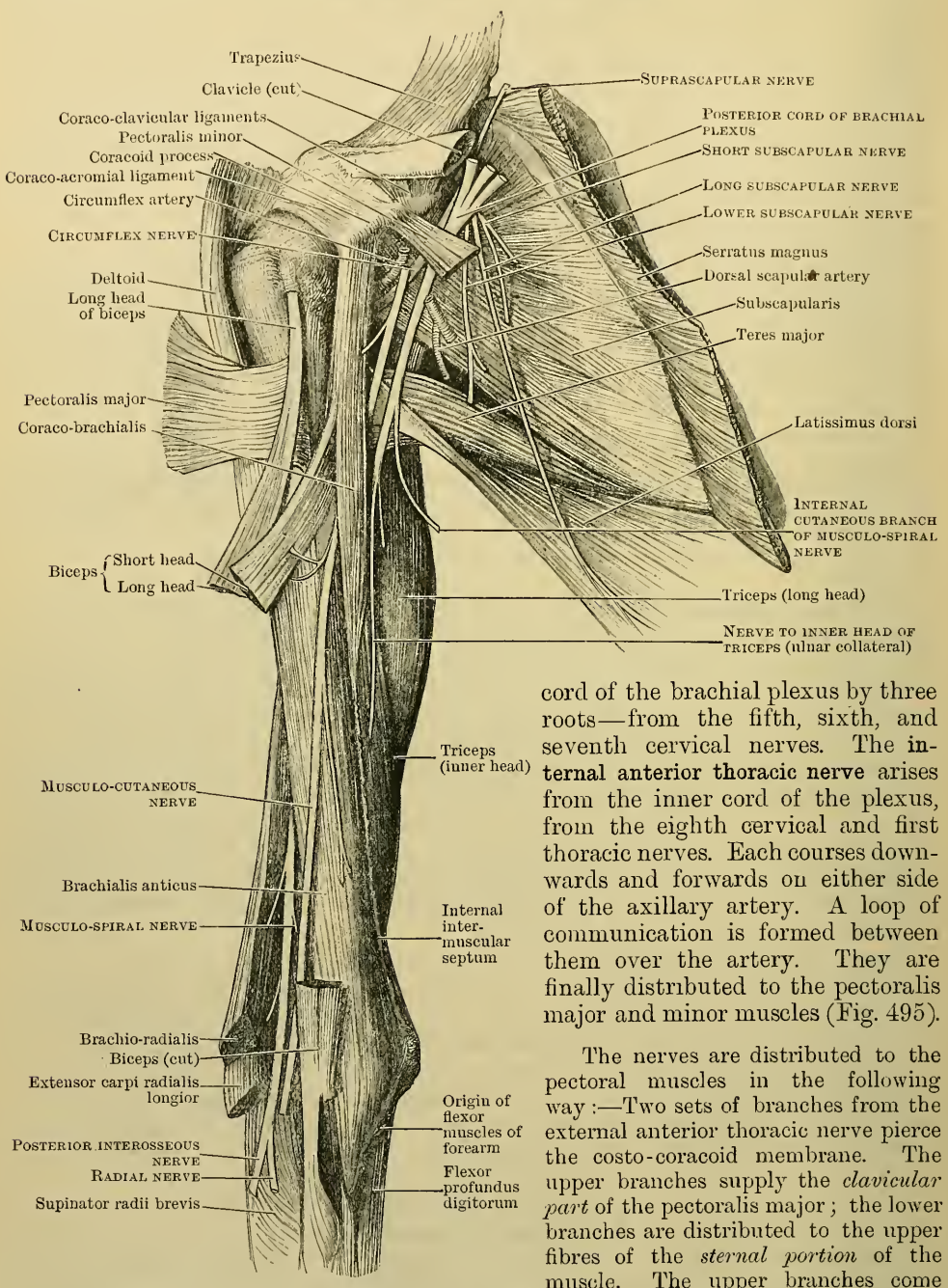


Fig. 496.—The Posterior Wall of the Axilla and the Front of the Arm (the biceps being divided).

The nerves are distributed to the pectoral muscles in the following way:—Two sets of branches from the external anterior thoracic nerve pierce the costo-coracoid membrane. The upper branches supply the *clavicular part* of the pectoralis major; the lower branches are distributed to the upper fibres of the *sternal portion* of the muscle. The upper branches come from the fifth and sixth cervical nerves; the lower branches, from the fifth, sixth, and seventh nerves. The *pectoralis minor* is pierced by two sets of nerves—the upper set is derived from the loop of communication between the external and internal anterior thoracic nerves over the axillary artery; the lower set is derived from the internal anterior thoracic nerve alone. These nerves supply the *pectoralis minor* muscle, and, after piercing it, supply the *sternal part* of the pectoralis major. The lower nerve, in

many cases, sends its branches to the pectoralis major round the lower border of the pectoralis minor, and it may supply on its way the *axillary arches*, if present. These two branches are derived—the upper from the seventh, eighth cervical, and first thoracic nerves; the lower from the eighth cervical and first thoracic nerves. The pectoral muscles are thus both supplied by the two anterior thoracic nerves. The clavicular fibres of the pectoralis major are innervated by the fifth and sixth nerves; the sternal fibres, from above downwards, by the fifth, sixth, seventh, and eighth cervical, and first thoracic nerves; and the pectoralis minor is supplied by the seventh and eighth cervical, and first thoracic nerves.

Musculo-Cutaneous Nerve.

The **musculo-cutaneous nerve** (n. musculo-cutaneus) takes origin from the outer cord of the plexus, from the fifth and sixth cervical nerves (Fig. 496). The **nerve to the coraco-brachialis muscle**, arising from the seventh or sixth and seventh nerves, is usually associated with it. Separating from the outer head of the median nerve, the musculo-cutaneous nerve lies at first between the coraco-brachialis muscle and the axillary artery. It is then directed downwards between the two parts of the coraco-brachialis, and passes between the biceps and brachialis anticus muscles, to the bend of the elbow. In its course it may send a branch under the biceps to join the median nerve. It pierces the deep fascia over the front of the elbow, between the biceps and brachio-radialis, and terminates in cutaneous branches for the supply of the outer side of the forearm.

The branches of the nerve are muscular and cutaneous. The **muscular branches** are supplied to the two heads of the biceps and the brachialis anticus, as the nerve lies between the muscles. The nerve to the coraco-brachialis (usually incorporated with the trunk of the musculo-cutaneous nerve) has an independent origin from the seventh or sixth and seventh nerves. It is usually double, one branch entering each portion of the muscle. The **cutaneous branches** are anterior and posterior (Fig. 497, p. 628). The **anterior branch** descends along the front of the outer side of the forearm to the wrist, and supplies an area extending inwards to the middle line of the forearm anteriorly, and downwards so as to include the ball of the thumb. It communicates above the wrist with the radial nerve, and supplies branches to the radial artery. The **posterior** branch passes backwards and downwards over the extensor muscles and supplies the skin on the outer aspect of the forearm posteriorly in its upper three-fourths, communicating with the cutaneous branches of the musculo-spiral nerve.

In addition to the above branches, the musculo-cutaneous nerve supplies in many cases the following small twigs in the arm: (1) a medullary branch to the humerus; (2) a periosteal branch to the lower end of the humerus on its anterior surface; and (3) a branch to the brachial artery.

Median Nerve.

The **median nerve** (n. medianus) arises by two roots—one from the outer cord, the other from the inner cord of the brachial plexus. The outer head, from the (fifth), sixth, and seventh nerves, descends along the outer side of the axillary artery; the inner head, from the eighth cervical and first thoracic nerves, crosses the end of the axillary artery or the beginning of the brachial artery, to join the other head in the upper part of the arm. Descending along the outer side of the brachial artery, the nerve crosses over it obliquely in the lower half of the arm. In the hollow of the elbow, it lies internal to the brachial artery, beneath the bicipital fascia and the median basilic vein. It passes into the forearm between the two heads of the pronator radii teres muscle, separated from the ulnar artery by the deep origin of that muscle. Extending down the middle of the forearm, between the superficial and deep muscles to the wrist, it enters the palm of the hand on the outer side of the flexor tendons of the fingers beneath the anterior annular ligament. In the hand it spreads out at the lower border of the annular ligament beneath the palmar fascia and superficial palmar arch, and separates into its six terminal branches. In the forearm a small artery accompanies it,—the comes nervi mediani. Above the wrist it is comparatively superficial, lying on the outer side of the superficial flexor tendons and directly beneath the tendon of the palmaris longus.

Communications.—(1) The median, in some cases, receives a communicating branch from the musculo-cutaneous nerve in the arm. (2) It communicates in some cases, in the upper part of the forearm, with the ulnar nerve beneath the flexor muscles. (3) It communicates by means of its cutaneous branches with the ulnar nerve in the palm of the hand.

Branches.—The median nerve usually gives off no branches in the upper arm.

Branches in the Forearm.—(1) **Articular Branches.**—Minute articular filaments are distributed to the front of the elbow-joint.

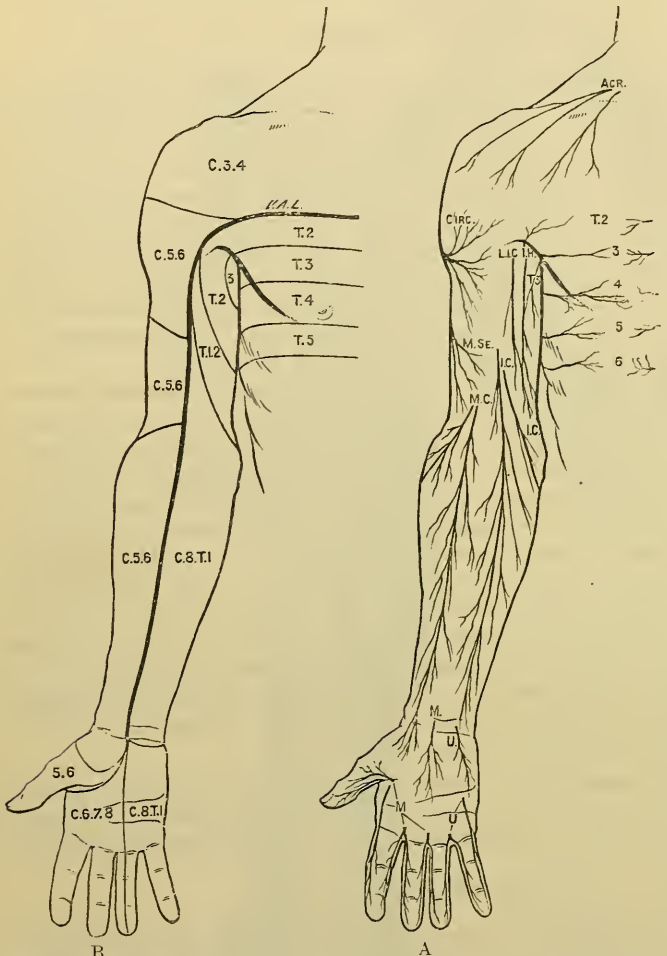


FIG. 497.—THE DISTRIBUTION OF CUTANEOUS NERVES ON THE FRONT OF THE ARM AND HAND.

(A) represents the distribution of the several nerves, the letters indicating their nomenclature. ACR, Acromial branch (cervical plexus); CIRC, Cutaneous branch of circumflex nerve; M.SE, Superior external cutaneous branch of musculo-spiral nerve; M.C, Musculo-cutaneous nerve; M, Median nerve; U, Ulnar nerve; I.C, Internal cutaneous nerve; L.I.C, Lesser internal cutaneous nerve (Wrisberg); I.H, Intercosto-humeral nerve; T.2, 3, 4, 5, 6, Anterior and lateral branches of intercostal nerves.

(B) is a schematic representation of the areas supplied by the above nerves, the lettering indicating the spinal origin of the branches of distribution to each area. V.A.L, Ventral axial line.

(2) **Muscular Branches.**—Just below the elbow a bundle of nerves arise which is distributed to the following muscles: pronator radii teres, flexor carpi radialis, palmaris longus, flexor sublimis digitorum. Nerves are also generally traceable from this bundle to the upper fibres of the flexor longus pollicis and flexor profundus digitorum. The nerve to the pronator radii teres often arises independently in the hollow of the elbow.

(3) The **anterior interosseous nerve** arises from the back of the median nerve in the forearm, descends in front of the interosseous membrane along with the anterior interosseous artery, passes behind the pronator quadratus muscle, and terminates by supplying articular filaments to the radio-carpal articulation. In its course the nerve supplies muscular branches to the flexor longus pollicis, the outer half of the flexor profundus digitorum, and the pronator quadratus, minute medullary branches to the radius and ulna, and twigs to the periosteum and interosseous membrane.

(4) **Palmar Cutaneous Branch.**—In the lower third of the forearm a small cutaneous branch arises, which pierces the deep fascia and crosses the anterior annular ligament to reach the palm of the hand. It supplies the skin of the palm and communicates with a similar branch of the ulnar nerve. This branch is not always present.

Branches in the Hand.—In the hand the median nerve gives off its terminal branches. These are muscular and cutaneous.

The main **muscular branch** arises just below the anterior annular ligament and passes outwards to the base of the thenar eminence; entering the ball of the thumb superficially on the inner side, it supplies branches to the abductor pollicis, opponens pollicis, and the superficial head of the flexor brevis pollicis.

The **cutaneous branches** are five in number. Three separate branches supply each side of the thumb and the radial side of the index finger. The two remaining branches subdivide at the cleft between the second and third, and the third and fourth fingers respectively, into branches which supply the adjacent sides of the second and third, and the third and fourth fingers. From the nerves which supply respectively the radial side of the index finger, and the contiguous sides of the index and third fingers, fine muscular branches arise for the two outer lumbrical muscles. The cutaneous branches of the median nerve are placed in the palm between the superficial palmar arch and the flexor tendons. They become superficial at the roots of the fingers between the slips of the palmar fascia, or, in the case of the nerves to the thumb and radial side of the index finger, at the outer edge of the central portion of the palmar fascia. In the fingers they are placed superficial to the digital arteries, and are distributed to the sides and front of the fingers. Each nerve supplies one or more dorsal branches, distributed to the skin on the dorsal aspect of the terminal phalanx of the thumb and the two distal phalanges of the first two and a half fingers, thus making up for the deficiency of the radial nerve in these situations.

Ulnar Nerve.

The **ulnar nerve** (n. ulnaris) arises from the inner cord of the brachial plexus, from the eighth cervical and first thoracic nerves. It also occasionally has a root from the outer cord of the plexus (seventh cervical nerve). In the axilla it lies between the axillary artery and vein, and behind the internal cutaneous nerve; in the upper half of the upper arm it lies on the inner side of the brachial artery in front of the triceps muscle. In the lower half of the arm it is separated from the brachial artery; and passing behind the intermuscular septum, and in front of the inner head of the triceps in company with the inferior profunda artery, it reaches the interval between the internal condyle of the humerus and the olecranon process. It is here protected by an arch of deep fascia stretching between the internal condyle and the olecranon process. It enters the forearm between the humeral and ulnar origins of the flexor carpi ulnaris, and courses downwards between the flexor carpi ulnaris and flexor profundus digitorum. In the lower half of the forearm it becomes comparatively superficial, lying on the inner side of the ulnar artery beneath the tendon of the flexor carpi ulnaris. Just above the anterior annular ligament of the wrist, and external to the pisiform bone, it pierces the deep fascia in company with the artery and passes into the hand over the anterior annular ligament. Reaching the palm it divides beneath the palmaris brevis muscle into its two terminal branches, superficial and deep.

Communications.—(1) The ulnar nerve communicates in some cases with the median nerve in the forearm; (2) with the internal cutaneous and sometimes the median nerve by its palmar cutaneous branch; (3) with the cutaneous part of the median nerve in the palm by means of its terminal cutaneous branches; (4) with the radial nerve on the dorsum of the hand by means of its dorsal branch.

Branches.—The ulnar nerve gives off no branches till it reaches the forearm.

In the forearm it gives off articular, muscular, and cutaneous branches.

The **articular branch** is distributed to the elbow joint and arises as the nerve passes behind the internal condyle.

The **muscular branches** arise as soon as the nerve enters the forearm. They are distributed to the muscles between which the ulnar nerve lies—the flexor carpi ulnaris and the inner half of the flexor profundus digitorum.

The **cutaneous branches** are two in number, palmar and dorsal.

The **palmar cutaneous branch** is variable in size and position. It pierces the deep fascia in the lower third of the forearm and passes to the hypothenar eminence and palm of the hand, to the skin over which it is distributed. It gives branches to the ulnar artery, and communicates often with the internal cutaneous and palmar branch of the median nerve.

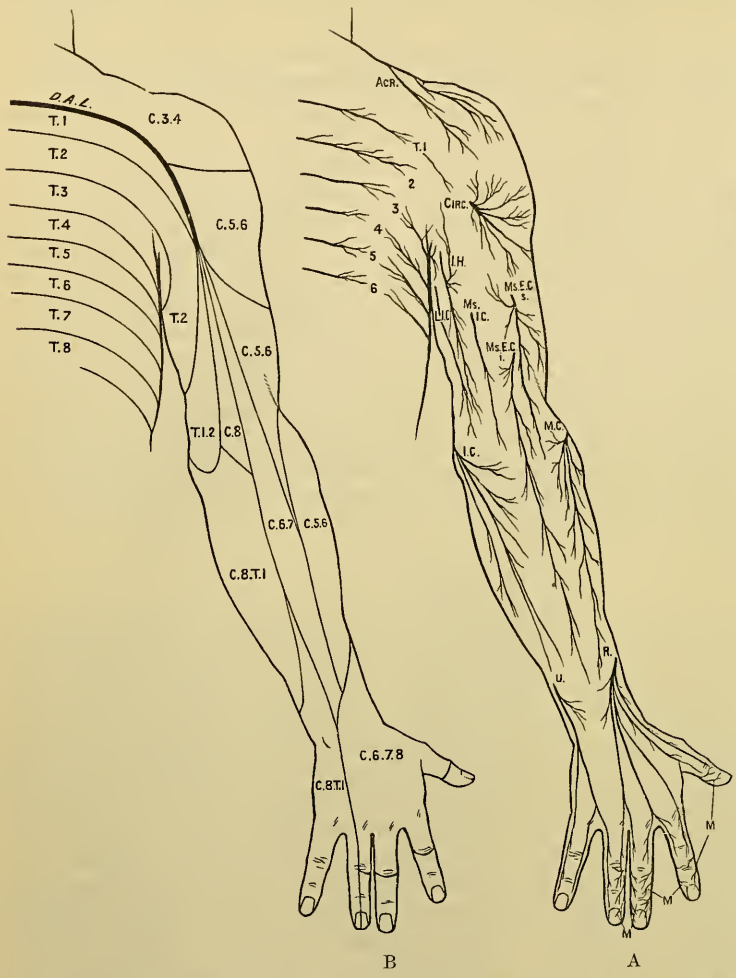


Fig. 498.—The Distribution of Cutaneous Nerves on the Back of the Arm and Hand.

(A) represents the distribution of the several nerves, the letters indicating their nomenclature. Acr, Acromial branches (cervical plexus); Circ, Cutaneous branch of circumflex nerve; Ms.E.C.s, Ms.E.C.i, Superior and inferior external cutaneous branches of musculo-spiral nerve; M.C, Musculo-cutaneous nerve; R, Radial nerve; M, Branches of median nerve to fingers; U, Ulnar nerve; I.C, Internal cutaneous nerve; Ms.I.C, Internal cutaneous branch of musculo-spiral nerve; L.I.C, Lesser internal cutaneous nerve (Wrisberg); I.H, Intercosto-humeral; T.1, 2, 3, 4, 5, 6, Lateral and posterior branches of upper thoracic nerves.

(B) is a schematic representation of the areas supplied by the above nerves, the lettering indicating the spinal origin of the branches of distribution to each area. D.A.L, Dorsal axial line.

The **dorsal cutaneous branch** is much larger (Fig. 498). It arises from the ulnar nerve in the middle third of the forearm; and, directed obliquely downwards and backwards beneath the tendon of the flexor carpi ulnaris, it becomes cutaneous on the inner side of the forearm in its lower fourth. It passes on to the back of the hand, and after giving off branches to the skin of the wrist and hand, which communicate with the radial nerve, it terminates in two branches, to supply the little finger and half the ring-finger in the following way:—the inner branch courses along the inner side of the dorsum of the hand and little finger: the outer branch subdivides at the cleft between the ring and little fingers to supply the adjacent sides of these fingers; this branch communicates with the radial nerve. The nerve may supply two and a half fingers on the dorsum of the hand.

In the palm the ulnar nerve supplies a small muscular branch to the palmaris brevis muscle, and then subdivides into its terminal branches, which are named superficial and deep.

The **superficial branch** is purely cutaneous; it passes downwards beneath the palmar fascia, and subdivides into an inner and an outer branch. The inner branch courses along the inner border of the little finger, which it supplies on its

palmar aspect. The outer branch becomes superficial at the cleft between the fourth and fifth fingers, between the slips of the palmar fascia, and subdivides into two branches which supply the adjacent sides of these fingers on their palmar aspect. It communicates with the adjacent digital branch of the median nerve.

The **deep branch** is purely muscular. It separates from the superficial branch, and passes deeply between the flexor brevis and abductor minimi digiti muscles; it supplies these muscles and the opponens minimi digiti, and, turning outwards along the line of the deep palmar arch and under cover of the deep flexor tendons, it supplies branches to the following muscles: interossei, two inner (third and fourth) lumbricales (on their deep surfaces), the adductores pollicis, obliquus and transversus, and deep part of the flexor brevis pollicis.

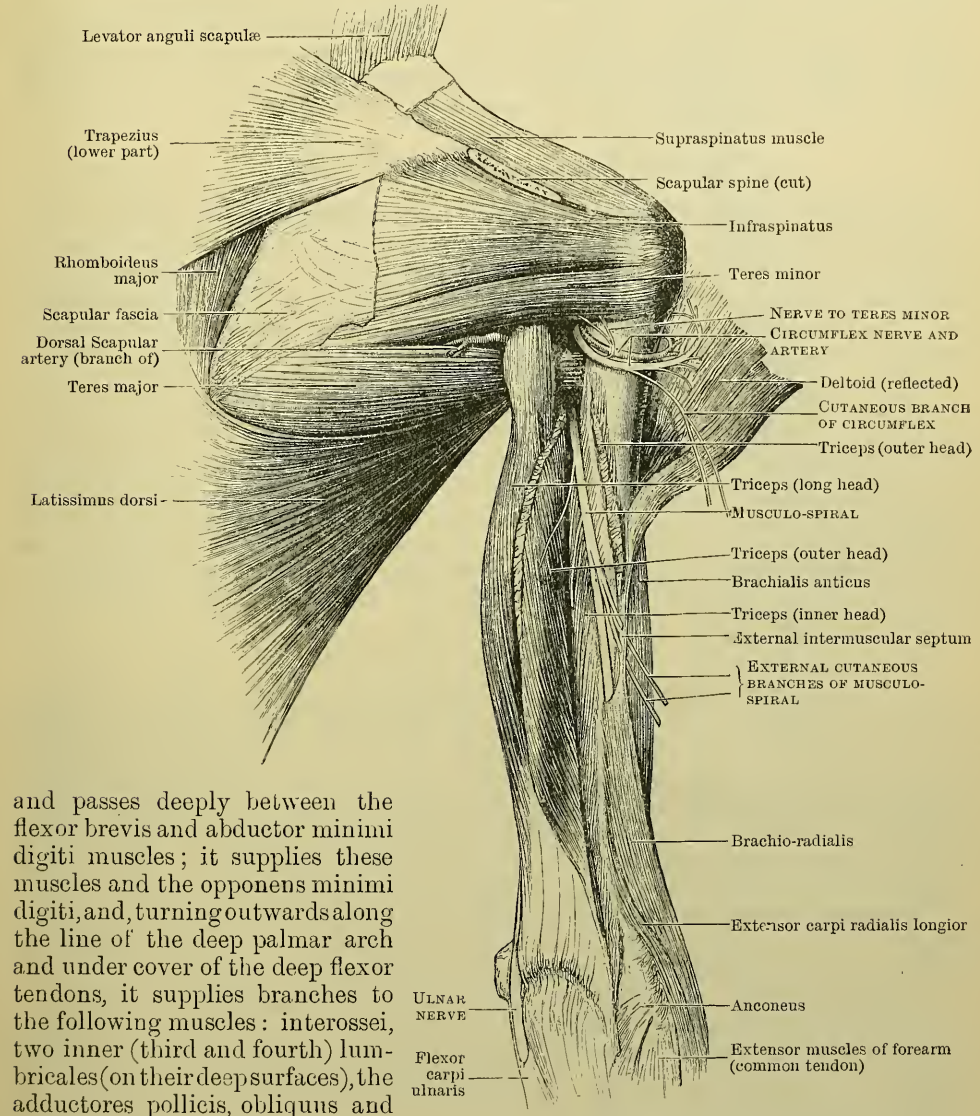


FIG. 499.—DELTOID REGION AND BACK OF ARM.

INTERNAL CUTANEOUS NERVE.

The **internal cutaneous nerve** (n. cutaneus brachii medialis) arises from the inner cord of the brachial plexus, from the eighth cervical and first thoracic nerves (Figs. 497 and 498). In the axilla and upper half of the arm it lies superficial to the main artery. It becomes cutaneous by piercing the deep fascia about the middle of the inner side of the upper arm, and accompanying the basilic vein through the lower half of the arm, it divides at the front of the elbow into its two terminal branches.

Communication.—The internal cutaneous nerve communicates with the palmar branch of the ulnar nerve in the lower part of the forearm.

Branches.—In the arm, as soon as it becomes superficial, the internal cutaneous nerve gives off a branch which supplies the skin of the lower half of the anterior surface of the arm on its inner side. At the elbow it divides into two terminal branches—anterior and internal, which, crossing over or under the median basilic vein, are distributed to the inner side of the forearm.

The **anterior branch** can be followed to the wrist and supplies the whole of the front of the forearm in the inner half; the **internal branch** is not so large, and, passing obliquely backwards and downwards over the origins of the pronator and flexor muscles, it is distributed to the upper two-thirds or three-fourths of the posterior aspect of the forearm on the inner side.

Lesser Internal Cutaneous Nerve.

The **lesser internal cutaneous nerve** (n. cutaneus brachii medialis minor) arises from the inner cord of the brachial plexus, and ultimately from the first thoracic nerve (Fig. 494, p. 624). It lies at first between the axillary artery and vein; and after descending over, under, or even, in some cases, through the axillary vein, it perforates the deep fascia on the inner side of the arm, and is distributed to the skin of the arm for the upper half or more on its inner side.

The nerve varies considerably in size. It may be absent, its place being taken by branches of the intercosto-humeral or by branches from the internal cutaneous offset of the musculo-spiral nerve. It generally bears a distinct relation in size to the intercosto-humeral, due to the fact that the size of the latter depends upon the size of the part of the second thoracic nerve connected with the first in the thorax. If an intra-thoracic connexion occurs between the first and second thoracic nerves, the intercosto-humeral may be deprived of a certain number of its fibres, which in that case reach the upper limb through the lesser internal cutaneous nerve. When traced up to the plexus the lesser internal cutaneous is found to have an origin from the back of the cord formed by the eighth cervical and first thoracic nerves, and usually receives fibres from the first thoracic nerve only. In cases where "*axillary arches*" are present they may be supplied by this nerve.

Circumflex Nerve.

The **circumflex nerve** (n. axillaris), at its origin is just below the supra-scapular and comes from the same spinal nerves—the fifth and sixth cervical nerves (Fig. 494, p. 623). Extending downwards and outwards behind the axillary artery, it leaves the axilla by passing round the external border of the subscapularis muscle, in company with the posterior circumflex artery, in a quadrilateral space bounded by the humerus, subscapularis, triceps (long head), and teres major. Winding round the surgical neck of the humerus from within outwards, it terminates under the deltoid by supplying that muscle (Fig. 499, p. 631).

Branches.—**Muscular branches** are supplied to the teres minor and deltoid muscles. The nerve to the teres minor enters the outer side of the muscle. It possesses a pseudo-ganglion, a thickening of fibrous tissue, on its trunk.

Articular branches enter the back part of the capsule of the shoulder-joint.

A **cutaneous branch** (n. cutaneus brachii lateralis) of considerable size passes obliquely downwards and forwards from beneath the deltoid muscle, becoming superficial at its posterior border. Sometimes the branches pierce the muscle. It supplies the skin over the insertion of the deltoid and the upper half of the arm on the outer side (Fig. 498, p. 630).

Musculo-Spiral Nerve.

The **musculo-spiral** nerve (n. radialis) appears to be the continuation into the upper limb of the posterior cord of the brachial plexus. It usually takes origin from all the nerves which form the posterior cord—the fifth, sixth, seventh, and eighth cervical nerves (Fig. 494, p. 623). In a minority of cases the first thoracic contributes a few fibres, and more frequently the fifth cervical nerve is excluded from it. It extends from the axilla round the back of the humerus to the bend of the elbow, where it ends by dividing into its terminal branches.

In the axilla it lies behind the axillary artery, and in front of the subscapularis, teres major, and latissimus dorsi muscles.

In the arm, in the upper third, it lies on the inner side of the humerus behind the brachial artery, and upon the long head of the triceps. In the middle third of the arm it courses obliquely outwards and downwards in the spiral groove of the humerus, along with the superior profunda artery, separating the long, external, and internal heads of the triceps muscle (Fig. 499, p. 631). In the lower third of the arm, piercing the upper part of the intermuscular septum at the outer border of the triceps muscle, it descends to the bend of the elbow in front of the external condyle of the humerus, in the interval between the brachio-radialis and brachialis anticus muscles. Under cover of the former muscle, in the hollow of the elbow, it divides into its two terminal branches, the radial and posterior interosseous nerves.

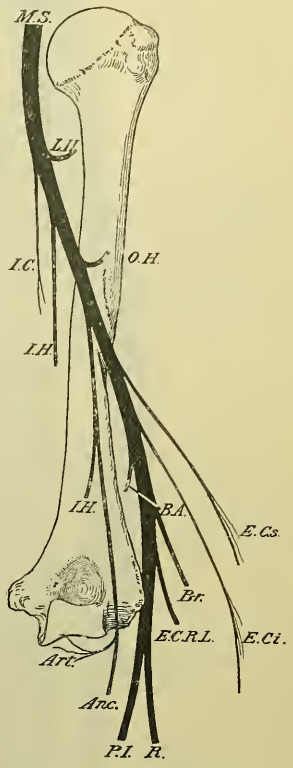


Fig. 500.—Diagrammatic Representation of the Branches of the Musculo-spiral Nerve.

M.S, Musculo-spiral nerve; L.H, Nerve to long head of triceps; I.C, Internal cutaneous branch; I.H, Nerve to inner head of triceps; O.H, Nerve to outer head of triceps; I.H, Second nerve to inner head of triceps; Anc. Nerve to anconeus; Art, Articular branch; E.Cs, Superior, external cutaneous branch; E.Ci, Inferior external cutaneous branch; B.A, Nerve to brachialis anticus; Br, Nerve to brachio-radialis; E.C.R.L, Nerve to extensor carpi radialis longior; P.I, Posterior interosseous nerve; R, Radial nerve.

The **collateral branches** are in three sets, arising (*a*) on the inner side, (*b*) on the back, and (*c*) on the outer side of the humerus (Fig. 500).

Branches arising internal to the humerus.—1. **Internal cutaneous** (n. cutaneus brachii posterior).—This branch, arising in common with one of the following, or independently, pierces the fascia on the inner side of the arm near the axilla. It supplies the skin of the inner side of the arm in the upper third, above and behind the area supplied by the lesser internal cutaneous nerve (Fig. 498, p. 630). This nerve varies in size, according to the bulk of the lesser internal cutaneous and intercosto-humeral nerves.

2. **Muscular branches** (rr. musculares).—These are in two sets. One series supplies the long head of the triceps muscle near its origin; the other series enters the inner head of the muscle. One of the latter, separating itself from the rest, accompanies the ulnar nerve in the middle third of the arm, and supplies the lower part of the muscle. This is sometimes called the **collateral ulnar nerve.**

Branches arising on the back of the humerus.—**Muscular branches** arise from the nerve in the musculo-spiral groove for the supply of all three heads of the triceps muscle. The branch which enters the inner head of the muscle, besides supplying it, passes through the muscle and behind the external condyle of the humerus, to terminate in the anconeus.

Branches arising at the outer side of the humerus.—1. The **cutaneous branches** (n. cutaneus antibrachii dorsalis) are two in number, superior and inferior. Arising from the musculo-spiral nerve before it pierces the external intermuscular septum, these branches pierce the deep fascia close together on the outer side of the arm in its lower half. Descending over the back of the external condyle, the *superior branch* supplies the skin of the outer side and back of the arm in its lower third, and the back of the forearm in its upper half. The *inferior branch* supplies an area of skin on the back of the forearm in the upper two-thirds internal to the area innervated by the musculo-cutaneous nerve (Fig. 498, p. 630).

2. **Muscular branches.**—The musculo-spiral nerve, as it lies in the interval between the brachialis anticus and brachio-radialis, supplies a small branch to the brachialis anticus (which in some cases is not present) and nerves to the brachio-radialis and extensor carpi radialis longior. It may also provide the nerve to the extensor carpi radialis brevior.

Radial Nerve.

The **radial nerve** (r. superficialis) is entirely cutaneous in its distribution. Arising in the hollow of the elbow beneath the brachio-radialis, it courses downwards under cover of that muscle through the upper two-thirds of the arm, and accompanies the radial artery in the middle third of the forearm. It then passes backwards beneath the tendon of the brachio-radialis and pierces the deep fascia in the outer side of the forearm in the lower third. It is distributed to the skin of the back of the wrist, the outer side and the back of the hand, and the back of the thumb and outer two and a half fingers (Fig. 498, p. 630). Its branches communicate on the ball of the thumb with the musculo-cutaneous nerve, and on the back of the hand with the dorsal branch of the ulnar nerve. The digital branches are small, and are five in number. Two pass to the back of the thumb and reach the inter-phalangeal articulation. One supplies the radial side of the index finger as far as the second phalanx. The remaining two branches divide at the clefts between the second and third, and third and fourth fingers respectively, and innervate the adjacent sides of these fingers as far as the second phalanx. The rest of the skin of these digits to the tips is supplied by digital branches of the median nerve. The nerve may only supply one and a half fingers, being replaced by branches from the ulnar nerve.

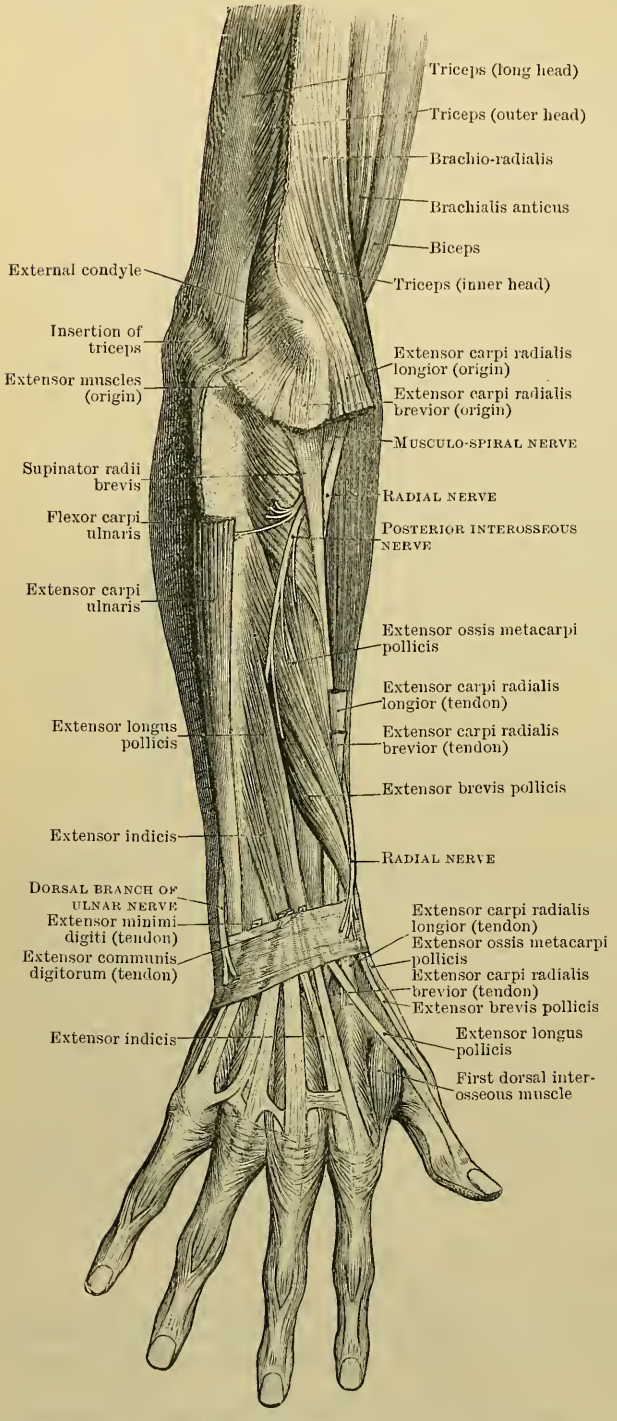


Fig. 501.—The Muscles of the Back of the Forearm (the superficial muscles have been reflected).

Posterior Interosseous Nerve.

The **posterior interosseous nerve** (r. profundus, n. interosseus antibrachii dorsalis) is entirely muscular and articular in its distribution, and it arises like the radial beneath the brachio-radialis muscle. Directed obliquely downwards and backwards, it

reaches the back of the forearm, after passing round the outer side of the radius, by piercing the fibres of the supinator radii brevis muscle (Fig. 501). On the back of the forearm it is placed in the upper part of its course beneath the superficial extensor muscles, and upon the supinator radii brevis and extensor ossis metacarpi pollicis, along with the posterior interosseous artery. In the lower half of the forearm it passes beneath the extensor longus pollicis, and lies upon the interosseous membrane. At the wrist it passes beneath the extensor tendons on to the back of the carpus, where it terminates in a gangliform enlargement of small size, from which branches pass to the inter-carpal articulations. The posterior interosseous nerve supplies the following branches:—

(1) Terminal **articular branches** to the carpal joints.

(2) **Muscular branches**, in its course through the forearm. Thus on the outer side of the radius it supplies the extensor carpi radialis brevior and the supinator brevis muscle before it enters the fibres of the last-named muscle. After emerging from the supinator brevis it supplies a large bundle of nerves which enter the extensor communis digitorum, extensor minimi digiti, and extensor carpi ulnaris near their origins. Lower down the forearm the nerve gives off branches to the extensor ossis metacarpi pollicis, extensor longus and extensor brevis pollicis, and extensor indicis.

Subscapular Nerves.

There are three subscapular nerves (nn. subscapulares) (Figs. 494 and 496).

The **first or short subscapular nerve** is generally double, and there may be three trunks present. It arises from the posterior cord of the plexus behind the circumflex nerve, and comes from the fifth and sixth cervical nerves. It passes downwards behind the axillary artery and enters the subscapularis muscle.

The **second or lower subscapular nerve** also arises behind the circumflex from the posterior cord of the plexus, and from the fifth and sixth cervical nerves. Its origin is below and external to that of the first nerve. It courses outwards and downwards behind the axillary artery, and the circumflex and musculo-spiral nerves to the teres major muscle. It supplies branches to the outer part of the subscapularis muscle and ends in the teres major.

The **third or long subscapular nerve** (n. thoraco-dorsalis) arises from the back of the posterior cord of the plexus, behind the musculo-spiral nerve, and from the sixth, seventh, and eighth cervical nerves, or from the seventh and eighth nerves only. It is directed downwards and outwards between the two previous nerves, behind the axillary artery and over the posterior wall of the axilla, in company with the subscapular artery, to the latissimus dorsi muscle, which it supplies on its anterior (inner) surface.

THORACIC NERVES.

The thoracic nerves are twelve in number, each nerve emerging below the corresponding vertebra and rib. Eleven of the series are intercostal, the twelfth lying below the last rib. The first, second, third, and twelfth nerves present peculiarities in their course and distribution. The other thoracic nerves, as already stated, are simple, and may be regarded as types both in course and distribution.

The **first thoracic nerve** is the largest of the series. It emerges from the spinal canal below the neck of the first rib, and divides in the first intercostal space into two very unequal, upper and lower, parts. The *upper* larger part ascends obliquely over the neck of the first rib, lying external to the superior intercostal artery, and enters the neck behind the subclavian artery and the pleura. It proceeds outwards upon the scalenus medius muscle and enters into the formation of the brachial plexus, as already described.

The *lower, intercostal part* of the nerve is much smaller in size. It courses forwards in the first intercostal space and supplies the intercostal muscles. It usually gives off no anterior branch to the skin of the chest and no lateral cutaneous branch.

In some cases a lateral cutaneous branch emerges from the side of the first intercostal space. This may be derived from the first nerve, or it may be the **intercosto-humeral nerve**, derived from the second thoracic nerve. In many cases an anterior cutaneous branch perforates the first intercostal space and supplies the skin on the front of the chest. This branch, similarly, is sometimes traceable to the second thoracic nerve.

Communications.—Besides its junction with the eighth cervical to form the brachial plexus, the first thoracic nerve effects the following communications:—(*a*) The last cervical or first thoracic ganglion of the sympathetic sends a gray ramus communicans to join the nerve on its appearance in the thorax. (*b*) The second thoracic nerve in a majority of cases communicates with the first. This communication varies considerably in size and distribution. It may reinforce the intercostal branch of the nerve, it may send one branch to the intercostal portion and another to the part of the nerve joining the brachial plexus, or it may consist of a nerve proceeding solely to join the brachial plexus by a junction in the first intercostal space with the part of the first thoracic nerve, which is engaged in forming the plexus. (*c*) It is possible that the first *white ramus communicans* in the thoracic region connects the first thoracic nerve with the gangliated cord of the sympathetic, but this is not known with certainty.

The **second thoracic nerve** is of large size, though much smaller than the first. It passes forwards in the second intercostal space, lying at first in the subcostal groove between the external and internal intercostal muscles. At the level of the mid-axillary line it gives off a large lateral branch; continuing its course it pierces the internal intercostal muscle and lies upon the pleura; finally, at the lateral border of the sternum, it passes forwards in front of the internal mammary artery and through the internal intercostal muscle, and the aponeurosis of the external intercostal muscle, and ends by supplying the skin of the front of the chest over the second intercostal space.

The nerve supplies the following branches:—

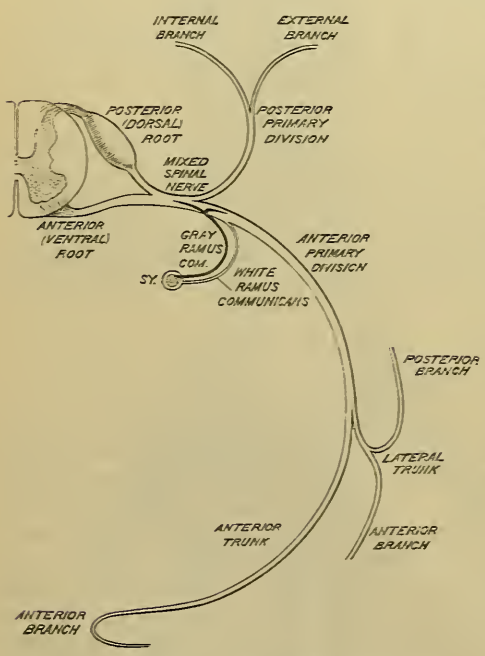


FIG. 502.—SCHEME OF THE DISTRIBUTION OF A TYPICAL SPINAL NERVE.

1. **Muscular branches** to the muscles of the second intercostal space.

2. **Cutaneous branches.** (*a*) **Anterior terminal branches** (rr. cutaneus anterior) to the skin over the second intercostal space (Fig. 503). (*b*) A large lateral cutaneous branch, the **intercosto-humeral nerve** (n. intercosto-brachialis) (Fig. 494, p. 623). This nerve pierces the intercostal muscles and the serratus magnus, and, crossing the axilla, extends to the arm. It pierces the deep fascia just beyond the posterior fold of the axilla, and can be traced down the arm as far as the interval between the internal condyle of the humerus and the olecranon process. It supplies an area of skin stretching across the armpit and along the posterior surface of the arm on the inner side as far as the elbow (Fig. 497, p. 628).

The intercosto-humeral nerve varies in size. It may pierce the first intercostal space, and it is often divisible into anterior and posterior branches, like the lateral branch of an ordinary intercostal nerve.

Communications.—(1) The intercosto-humeral nerve communicates with two adjacent nerves. Either before or after piercing the fascia of the axilla it is joined by the lesser internal cutaneous nerve of the brachial plexus. It also communicates with the posterior part of the lateral branch of the third intercostal nerve by means of the branches distributed to the floor and boundaries of the axilla. It may supply the axillary arches, when present. (2) Besides the branches referred to, the second thoracic nerve in many

cases transmits a nerve to the brachial plexus, which becomes incorporated with the first thoracic nerve after passing over the neck of the second rib. This branch is inconstant. As already mentioned, it may join only the intercostal part of the first thoracic nerve, it may join the brachial plexus only, or it may send branches to both parts of the first thoracic nerve. (3) Besides the communications effected by branches of the second thoracic nerve in its course, it also receives a *gray ramus communicans* from the second thoracic ganglion of the sympathetic cord in the thorax. It probably also sends to the sympathetic the first *white ramus communicans*, though this is not known with certainty.

The **third thoracic nerve** only differs from a typical thoracic nerve in one respect. Its **lateral branch** divides in the usual way into anterior and posterior parts, of which the latter is carried to the arm and supplies an area of skin on the posterior half of the inner side near the root of the limb. It effects a junction with the intercosto-humeral nerve (Fig. 494, p. 623).

The **fourth, fifth, and sixth thoracic nerves** have a course and distribution which is simple and typical. Except for the peculiarities above mentioned, the second and third thoracic nerves have a similar distribution.

The nerves appear on the posterior wall of the thorax, in the subcostal groove of the corresponding rib. They extend forwards between the intercostal

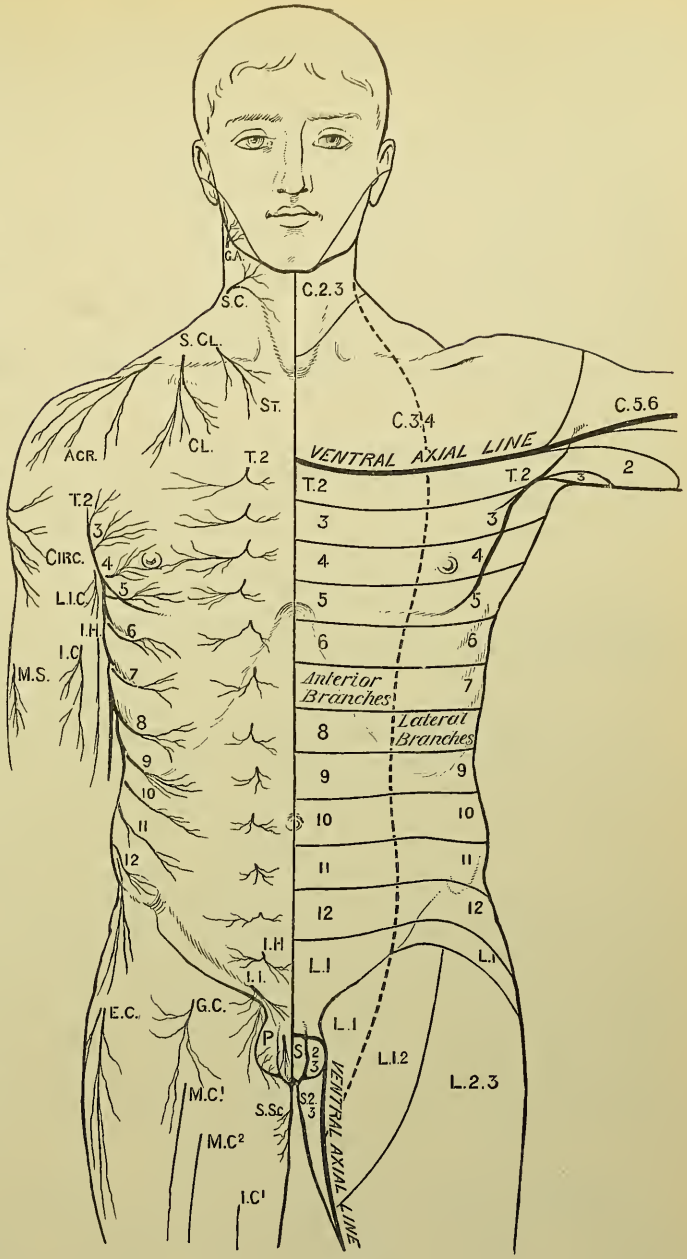


FIG. 503.—THE DISTRIBUTION OF CUTANEOUS NERVES ON THE FRONT OF THE TRUNK.

On one side the distribution of the several nerves is represented, the letters indicating their nomenclature.

G.A, Great auricular nerve; S.C, Superficial cervical nerve; S.Cl, Supra-clavicular nerves; ACR, Acromial; CL, Clavicular; ST, Sternal; T.2-12, Lateral and anterior branches of thoracic nerves; I.H, Ilio-hypogastric nerve; I.I, Ilio-inguinal nerve; CIRC, Cutaneous branch of circumflex nerve; L.I.C, Lesser internal cutaneous nerve; I.H, Intercosto-humeral; I.C, Internal cutaneous; M.S, Cutaneous branch of musculo-spiral nerve, E.C, External cutaneous nerves; G.C, Genito-crural nerve; M.C¹·², Middle cutaneous nerves; I.C¹, Branch of internal cutaneous nerve; P, Branches of pudic nerve; S.Sc, Branches of small sciatic nerve.

On the other side a schematic representation is given of the areas supplied by the above nerves, the numerals indicating the spinal origin of the branches of distribution to each area.

muscles as far as the middle of the chest wall, lying at a lower level than the intercostal vessels. At the side of the chest each nerve passes obliquely through the internal intercostal muscle, and comes to lie upon the pleura, triangularis sterni muscle, and internal mammary artery. Thereafter, piercing the fibres of the internal intercostal muscle and the aponeurosis of the external intercostal muscle, each nerve ends by supplying the skin of the front of the chest, over an area corresponding to the inner or anterior part of the intercostal space to which it belongs.

Branches.—Each intercostal nerve supplies, in addition to the anterior terminal cutaneous branches, *muscular branches* to the intercostal muscles and a **lateral trunk** (r. cutaneus, lateralis), which, piercing the intercostal muscles and the serratus magnus, divides into anterior and posterior branches for the innervation of the skin over the side of the chest. Each area of skin thus innervated is continuous anteriorly with the area innervated by the anterior terminal branches of the same nerves, and posteriorly with the areas supplied by their posterior primary divisions.

The upper six intercostal nerves supply the muscles of the first six intercostal spaces and the triangularis sterni (3, 4, 5, 6). The second, third, fourth, fifth, and sixth nerves supply the skin of the front of the chest: the second, opposite the manubrio-sternal joint; the sixth, opposite the base of the xiphoid cartilage. Their lateral branches supply branches to the intercostal muscles and the skin of the side of the chest, the second (intercosto-humeral) and the third in part being drawn out on to the arm. The fourth supplies the nipple (Fig. 503).

Communications.—Each of these intercostal nerves communicates with the sympathetic cord and ganglia by two branches—a *white ramus communicans* to the corresponding sympathetic ganglion or the adjacent part of the sympathetic cord; and a *gray ramus communicans*, which passes to each nerve from the corresponding ganglion.

The **seventh, eighth, ninth, tenth, and eleventh thoracic nerves** only differ from the preceding nerves in regard to a part of their course and distribution. Each has the same course and communications as the preceding nerves in the thoracic wall. In addition, these nerves have a further course and distribution in the abdominal wall. Each nerve traverses its intercostal space in the way described. At the anterior end of the space, the nerve pierces the attachment of the diaphragm and the transveralis abdominis muscles to the costal cartilages, and courses forwards in the abdominal wall between the transversalis and obliquus internus muscles. The nerve then passes between the rectus muscle and the posterior layer of its sheath, and eventually reaches the anterior abdominal wall and becomes cutaneous by piercing the rectus itself and the anterior layer of its sheath.

Muscular Branches.—The lower intercostal nerves supply the intercostal muscles of the spaces in which they lie; and in the abdominal wall they innervate the transversalis, obliqui, and rectus abdominis. The branches arise from the main trunk as well as from its lateral and anterior branches. (The ninth, tenth, and eleventh nerves are described as assisting in the innervation of the diaphragm by communications with the phrenic nerve.)

Cutaneous Branches.—These are lateral and anterior. The **lateral branches** divide into anterior and posterior parts, and, becoming superficial along the line of inter-digitation of the obliquus externus muscle with the serratus magnus and latissimus dorsi, they are directed more obliquely downwards than the lateral branches of the higher intercostal nerves, and are distributed to the skin of the loin as low down as the buttock. The lateral branch of the eleventh nerve can be traced over the iliac crest (Fig. 503).

The **anterior branches** are small. That of the seventh nerve innervates the skin at the level of the ensiform cartilage. The eighth and ninth appear between the ensiform cartilage and the umbilicus; the tenth nerve supplies the region of the umbilicus; and the eleventh, the area immediately below the umbilicus.

The cutaneous branches of these nerves, including the posterior primary divisions, thus supply continuous belts of skin, which can be mapped out on the body from the vertebral column behind to the middle line in front. These areas are not placed horizontally, but tend to be drawn downwards as the series is followed from the upper to the lower nerves.

The **twelfth thoracic nerve** is peculiar in its course and distribution. It

emerges below the last rib (Fig. 504), and passes outwards and downwards in the posterior abdominal wall under cover of the psoas muscle, and between the external arcuate ligament and the quadratus lumborum muscle; it pierces the transversalis muscle, and courses forwards in the interval between it and the obliquus internus as far as the sheath of the rectus muscle. After piercing the posterior layer of the sheath, the rectus muscle, and the anterior layer of the sheath, it terminates by supplying the skin of the anterior abdominal wall midway between the umbilicus and the pubis. The branches of the nerve are **muscular**, to the transversalis, obliqui, rectus, and pyramidalis muscles of the abdominal wall, and **cutaneous branches**, two in number—an *anterior terminal branch*, which supplies the skin of the anterior abdominal wall midway between the umbilicus and the pubis, and a large *lateral cutaneous* (iliac) *branch*, which, passing obliquely downwards through the lateral muscles of the abdominal wall, becomes superficial above the iliac crest, a couple of inches behind the anterior superior spine. It supplies the skin of the buttock as far down as a point below and in front of the great trochanter of the femur (Fig. 507, p. 645).

The twelfth thoracic nerve, in many cases, receives a **communicating branch** from the eleventh, near its origin, and still more frequently sends a fine branch to join the origin of the first lumbar nerve in the psoas muscle. It may communicate also with the ilio-hypogastric nerve, as they lie together in the abdominal wall.

THE LUMBO-SACRAL PLEXUS.

The lumbo-sacral plexus is formed by the union of the anterior primary divisions of the remaining spinal nerves — five lumbar, five sacral, and one coccygeal. Frequently, a fine communicating branch of the twelfth thoracic nerve joins the first lumbar nerve near its origin.

Of the nerves in question the first sacral is generally the largest in size, the nerves diminishing gradually above and rapidly below the first sacral. The plexus, for the most part, forms the nerves destined for the supply of the lower limb. In addition, however, nerves arise at its upper limit which are distributed to the trunk above the level of the limb, and at the lower end of the plexus nerves arise for the supply of the perineum.

Partly for convenience of description, and partly on account of the differences in position and course of some of the nerves emanating from it, the plexus is subdivided into three subordinate parts — lumbar, sacral or sciatic, and pudendal plexuses. There is, however, no strict line of demarcation between the three parts.

The **lumbar plexus** is formed by the first four lumbar nerves, and is often joined by a branch from the twelfth thoracic nerve as well. It is limited below by the fourth lumbar nerve (n. furcalis), which also enters into the composition of the sciatic or sacral plexus. The nerves of the lumbar plexus are formed in the loin, and supply that region as well as part of the lower limb. They are separated from the nerves of the sacral portion of the plexus by the articulation of the innominate bone with the sacrum.

The **sacral** or **sciatic plexus** is formed by the fourth and fifth lumbar, and the first two or three sacral nerves. It is generally limited below by the third sacral nerve (n. bigeminus), which also assists in forming the pudendal plexus. The nerves of the sacral plexus are placed on the posterior wall of the pelvis, and are destined almost entirely for the lower limb.

The **pudendal plexus** is formed by the second, third, fourth, and fifth sacral nerves, and the minute coccygeal nerve. It is placed on the back wall of the pelvis and supplies branches mainly to the perineum.

Communications with the Sympathetic.—Each of these nerves has communications with the gangliated cord of the sympathetic in the abdomen and pelvis.

Gray Rami Communicantes.—From the lumbar and sacral ganglia long slender *gray rami communicantes* are directed backwards and outwards over the bodies of the vertebræ, and (in the lumbar region) beneath the origins of the psoas muscle, to reach the anterior primary divisions of the nerves. These branches are irregular in their arrangement. A given nerve may receive branches from two ganglia, or one ganglion may send branches to two nerves. The rami are longer in the loin than in the pelvis, owing to the projection of the lumbar portion of the vertebral column.

White Rami Communicantes.—Certain lumbar and sacral nerves are also connected with the abdominal and pelvic sympathethic by means of *white rami communicantes.* From the first two, and possibly also the third and fourth lumbar nerves, white rami communi-

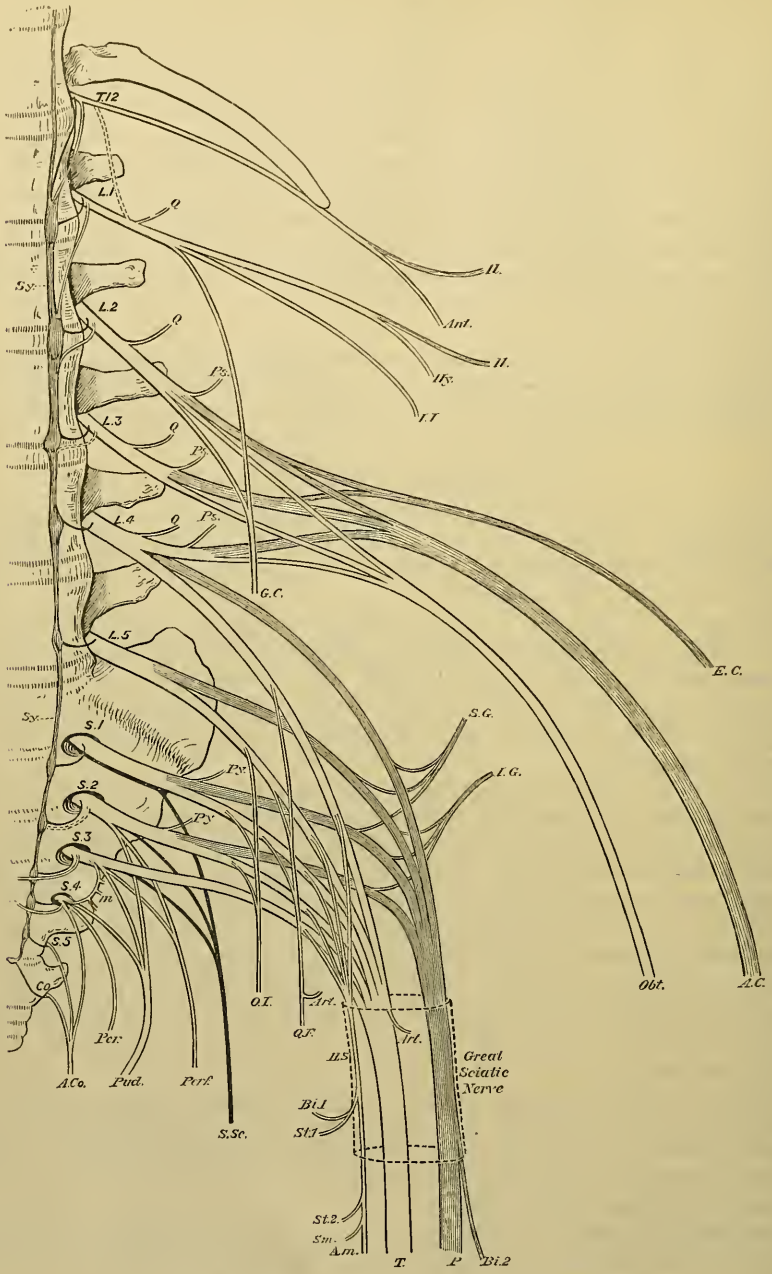


Fig. 504.—Nerves of the Lumbo-Sacral Plexus.

Sy, Sympathetic cord ; T.12, L.1, 2, 3, 4, 5, S.1, 2, 3, 4, 5, Co, Anterior primary divisions of the last thoracic, the lumbar, sacral, and coccygeal nerves ; Q, Nerves to quadratus lumborum ; Ps, Nerves to psoas muscle ; G.C, Genito-crural nerve ; Il, Iliac branches of last thoracic and ilio-hypogastric nerves ; Hy, Hypogastric branch of Ilio-hypogastric nerve ; I.I, Ilio-inguinal nerve ; E.C, External cutaneous nerve ; A.C, Anterior crural nerve ; Obt, Obturator nerve ; Py, Nerves to pyriformis muscle ; O.I, Nerve to obturator internus ; Q.F, Nerve to quadratus femoris muscle ; Art, Articular branch ; S.G. Superior gluteal nerve ; I.G, Inferior gluteal nerve ; P, Peroneal nerve ; Bi.2, Nerve to short head of biceps muscle ; T, Tibial nerve ; Art, Articular branch ; H.S, Nerve to the hamstring muscles ; Bi.1, Nerves to biceps (long head), and St.1, to semitendinosus ; St.2, Semitendinosus ; Sm, Semimembranosus ; A.m, Adductor magnus ; S.Sc, Small sciatic nerve ; Perf, Perforating cutaneous nerve ; Pud, Pudic nerve ; M. Muscular branches ; Per, Perineal branch of fourth sacral ; A.Co, Anterior sacro-coccygeal nerve.

cantes are directed forwards, either independently or incorporated with the corresponding gray rami, to join the upper part of the lumbar gangliated cord. The fifth lumbar nerve and the first sacral nerves are unprovided with white rami communicantes. From the third, and usually also the second or fourth sacral nerves, white rami (visceral branches) pass inwards, and, crossing over (without joining) the gangliated cord, enter the pelvic plexus of the sympathetic. The fifth sacral and coccygeal nerves possess no white rami communicantes.

THE LUMBAR PLEXUS.

The lumbar plexus is formed by the anterior primary divisions of the first three

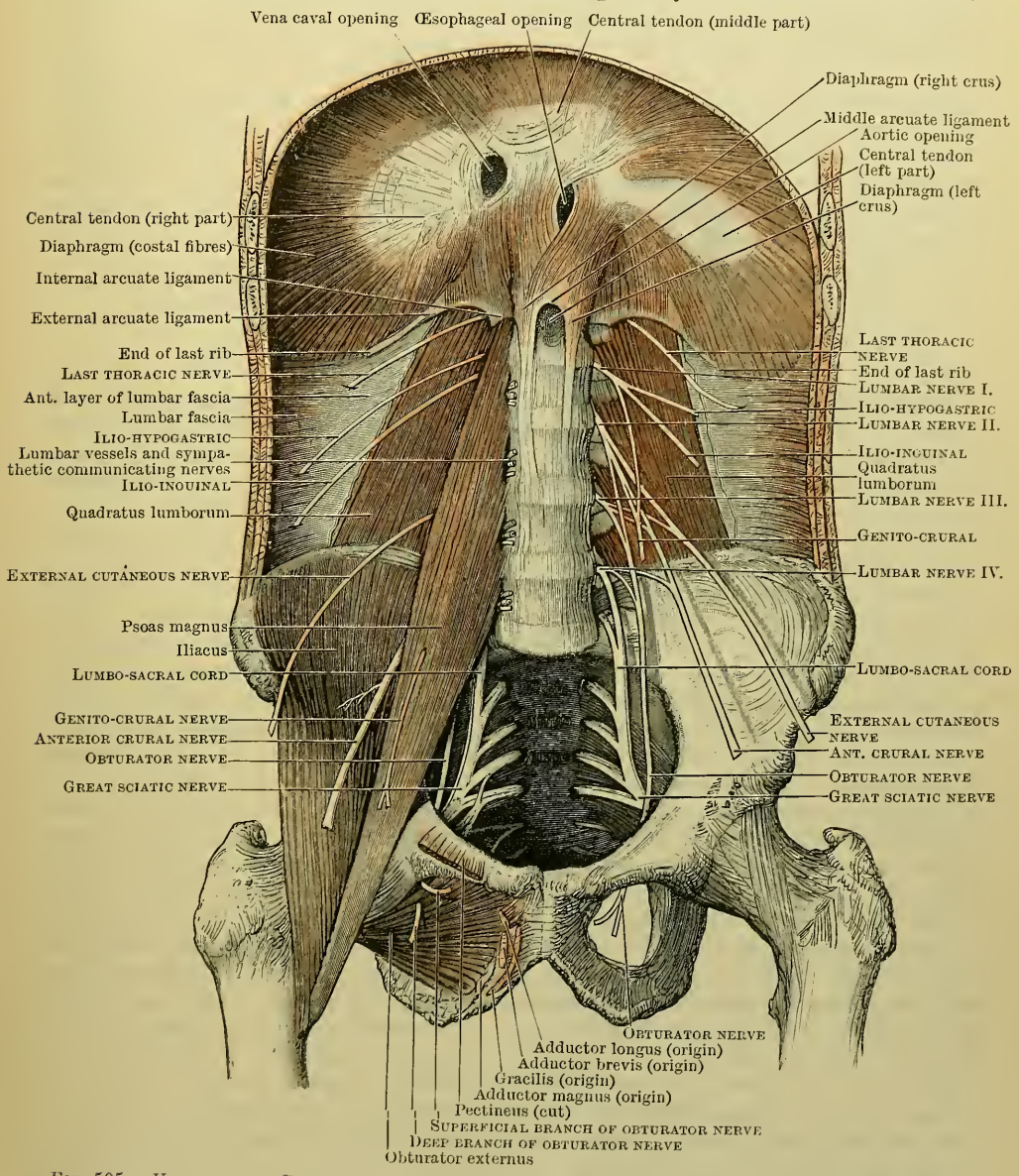


Fig. 505.—View of the Posterior Abdominal Wall, to show the Muscles and the Nerves of the Lumbo-Sacral Plexus.

and a part of the fourth lumbar nerves, with the addition, in some cases, of a small branch from the twelfth thoracic nerve. The nerves increase in size from above downwards (Fig. 505).

Position and Constitution.—The plexus is placed deeply in the substance of the psoas muscle, in front of the transverse processes of the lumbar vertebræ. The

nerves, on emerging from the intervertebral foramina, are connected as above described with the sympathetic system, and then divide in the following manner in the substance of the psoas muscle. The first and second nerves divide into upper and lower branches. The upper branch of the first nerve (which may be joined by the branch from the twelfth thoracic nerve) forms two nerves, **ilio-hypogastric** and **ilio-inguinal**. The lower branch of the first joins the upper branch of the second nerve, to produce the **genito-crural nerve**. The lower branch of the second nerve, the whole of the third, and that part of the fourth nerve engaged in the constitution of the plexus divide each into two unequal parts—smaller *anterior* and larger *posterior parts*. The smaller anterior portions combine together to form the **obturator nerve**, which is thus formed by the second, third, and fourth lumbar nerves. The root from the second nerve is not always present. The larger posterior portions of the same nerves combine together to form the **anterior crural nerve**. From the back of the posterior parts of the second and third nerves, the **external cutaneous nerve** arises. The nerves also provide, near their origins, irregular **muscular branches**, for the psoas and quadratus lumborum muscles. The following is a list of the nerves which spring from the lumbar plexus (Figs. 504 and 505):—

(1) Muscular branches to the quadratus lumborum and psoas.
(2) Ilio-hypogastric.
(3) Ilio-inguinal.
(4) Genito-crural.
(5) External cutaneous.
(6) Obturator.
(7) Anterior crural.

Muscular Branches.—The nerves to the **quadratus lumborum muscle** arise independently from the first three or four lumbar nerves (and sometimes also from the twelfth thoracic nerve). The nerves to the **psoas muscles** arise from the second and third lumbar nerves, with additions, in some cases, from the first or fourth. They are often associated in their origin with the nerve to the iliacus from the anterior crural. The **psoas minor**, when present, is innervated by the first or second lumbar nerve.

The ilio-hypogastric and ilio-inguinal nerves closely resemble in their course and distribution the lower thoracic nerves, with which they are in series.

The **ilio-hypogastric nerve** (n. ilio-hypogastricus) is the highest branch of the first lumbar nerve. It receives fibres also from the twelfth thoracic, when that nerve communicates with the first lumbar nerve. After traversing the psoas muscle obliquely, it appears at its outer border on the surface of the quadratus lumborum and behind the kidney. It courses through the loin, lying between the transversalis and obliquus internus muscles, above the crest of the ilium. About an inch in front of the anterior superior spine it pierces the obliquus internus, and continues its course in the groin beneath the aponeurosis of the obliquus externus. It finally becomes cutaneous in the anterior abdominal wall, by piercing the aponeurosis of the obliquus externus about an inch and a half above the external abdominal ring (Fig. 507 p. 645).

Its **branches** are—(1) *muscular* to the muscles of the abdominal wall; and (2) *cutaneous branches*, two in number. The **iliac branch** corresponds with the lateral branch of an intercostal nerve, and, after piercing the obliquus internus and obliquus externus, becomes cutaneous just above the iliac crest, below and behind the iliac branch of the last thoracic nerve. It is small, and may be absent. It is distributed to the skin over the upper part of the outer side of the buttock, in continuity with the cutaneous branch of the posterior primary division of the first lumbar nerve. The **hypogastric branch** is the anterior terminal branch of the nerve. It supplies the skin of the anterior abdominal wall below the level of the last thoracic nerve and above the pubis.

The **ilio-inguinal nerve** (n. ilio-inguinalis) is the second branch given off from the first lumbar nerve. It also may receive fibres from the last thoracic nerve. Not unfrequently the ilio-hypogastric and ilio-inguinal nerves are represented for a longer or shorter part of their course by a single trunk. When separate the nerve takes a course similar to that of the ilio-hypogastric nerve, but at a lower level, as far as the anterior abdominal wall. It then pierces the obliquus internus farther forward and lower down than the ilio-hypogastric; and coursing forwards

beneath the aponeurosis of the obliquus externus, just above Poupart's ligament, it becomes superficial after passing through the external abdominal ring and external spermatic fascia (Fig. 507, p. 645).

Its branches are *muscular* to the muscles of the abdominal wall, among which it passes, and *cutaneous branches*, which innervate the skin (1) of the anterior abdominal wall over the symphysis pubis, (2) of the thigh over the upper and inner part of Scarpa's triangle, and (3) of the upper part of the scrotum, and root and dorsum of the penis (of the mons Veneris and labium majus in the female). These last-named branches are contiguous to branches of the pudendal and pudic nerves. No lateral cutaneous branch arises from the ilio-inguinal nerve. It thus corresponds, like the hypogastric part of the ilio-hypogastric nerve, to the anterior trunk of a typical thoracic nerve.

The **genito-crural nerve** (n. genito-femoralis) usually arises by two independent roots from the front of the first and second lumbar nerves, which unite in the substance of the psoas to form a slender trunk. It appears on the posterior abdominal wall, lying on the psoas magnus, internal to the psoas parvus, and, piercing the psoas fascia, it extends downwards on the outer side of the common and external iliac vessels and behind the ureter to Poupart's ligament (Fig. 505, p. 641). At a variable point above that ligament it divides into genital and crural branches. The **genital branch** is a minute nerve. It crosses the terminations of the external iliac vessels, and, along with the vas deferens and spermatic vessels, enters the inguinal canal through the internal abdominal ring. It terminates by supplying small branches to the skin of the scrotum and adjacent part of the thigh. In the female it accompanies the round ligament to the labium majus. This nerve gives off in its course the following small branches: (1) to the external iliac artery; (2) to the cremaster muscle; (3) to communicate with the spermatic plexus of the sympathetic. The **crural branch** continues the course of the parent nerve into the thigh, lying on the outer side of the femoral artery. It becomes cutaneous by passing through the saphenous opening or the iliac portion of the fascia lata, and supplies an area of skin over Scarpa's triangle, external to that supplied by the ilio-inguinal nerve (Fig. 507, p. 645). It communicates in the thigh with the middle cutaneous branch of the anterior crural nerve. Before piercing the deep fascia it gives a minute branch to the femoral artery.

The **external cutaneous nerve** (n. cutaneus femoris lateralis) is only distributed to skin (Fig. 505). It arises from the back of the lumbar plexus, and usually from the second and third lumbar nerves. Emerging from the psoas muscle at its outer border, the nerve crosses the iliacus muscle, beneath the fascia iliaca, to reach the anterior superior iliac spine. It enters the thigh beneath the outer extremity of Poupart's ligament, and either over, under, or through the origin of the sartorius muscle. It extends down the outer side of the front of the thigh for a few inches, lying at first beneath the fascia lata, and afterwards in a tubular investment of the fascia. It gives off small branches in this part of its course, and finally, piercing the fascia about four inches below the anterior superior iliac spine, it separates into anterior and posterior terminal branches. The **anterior branch** is the larger, and is distributed on the outer side of the front of the thigh almost to the knee. The smaller **posterior branch** supplies the skin of the outer side of the buttock below the great trochanter and of the upper two-thirds of the outer side of the thigh (Fig. 507, p. 645).

Obturator Nerve.

The **obturator nerve** (n. obturatorius) supplies the muscles and skin on the inner side of the thigh. It arises in the substance of the psoas muscle by three roots placed in front of those of the anterior crural nerve, and derived from the second, third, and fourth lumbar nerves (Fig. 505, p. 641). Sometimes the root from the second nerve is absent. Passing vertically downwards, the nerve emerges from the psoas at its inner border, behind the common iliac, and on the outer side of the internal iliac vessels. It passes forwards below the pelvic brim in company with the obturator artery to the obturator groove of the thyroid foramen, through which it reaches the thigh. While in the obturator groove it separates into its two main branches, named superficial and deep (Fig. 506, p. 644).

The **superficial branch** enters the thigh in front of the obturator externus and adductor brevis muscles, and beneath the pectineus and adductor longus. In the middle third of the thigh it is found coursing along the inner border of the adductor longus, anterior to the gracilis; and it finally divides into two slender terminal filaments, of which one enters Hunter's canal and ends on the femoral artery, while the other supplies the skin for a variable distance on the inner side of the thigh and joins in the obturator (sub-sartorial) plexus.

The branches of the superficial part of the nerve are:—

1. An **articular branch** to the hip-joint which arises from the nerve as soon as it enters the thigh, and supplies the joint through the acetabular notch.

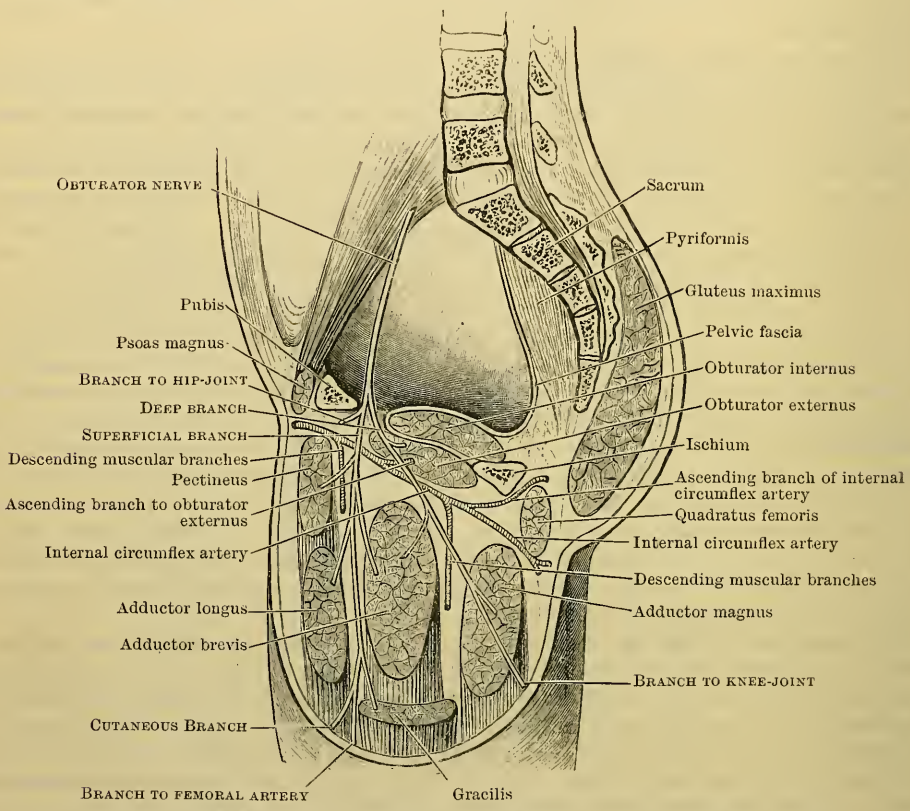


Fig. 506.—Scheme of the Course and Distribution of the Obturator Nerve.

2. **Muscular branches** to the adductor longus, gracilis, adductor brevis (usually), pectineus (occasionally). The last-named muscle is not usually supplied from the obturator nerve.

3. A **cutaneous branch** of very variable size forms one of the terminal branches (Fig. 507). It becomes superficial between the gracilis and adductor longus, in the middle third of the thigh, and may supply the skin of the lower two-thirds of the thigh in its inner side. It is generally of small size, and is connected with branches of the internal cutaneous and internal saphenous nerves behind the sartorius muscle to form the **obturator (sub-sartorial) plexus.** The branch from the internal saphenous nerve to the plexus passes inwards behind the sartorius after piercing the aponeurotic covering of Hunter's canal. The branch from the internal cutaneous nerve is generally superficial at the point of formation of the plexus.

4. The **branch to the femoral artery** is the other terminal branch of the nerve. It enters Hunter's canal along the inner edge of the adductor longus, and ramifies over the lower part of the artery.

5. A fine **communicating branch** sometimes joins the anterior crural nerve in front of the hip-joint.

The **deep part of the obturator nerve** reaches the thigh by piercing the

obturator externus muscle. It passes downwards between the adductor brevis and adductor magnus muscles. After passing obliquely through the adductor magnus, it appears in the popliteal space on the popliteal vessels, and terminates by piercing the posterior ligament and supplying the knee-joint.

Its branches are:—(1) **muscular branches** to the obturator externus, adductor magnus, and (when the muscle is not supplied by the superficial part of the nerve) the adductor brevis. The branch to the obturator externus arises before the nerve enters the muscle, in the obturator groove. The nerve to the adductor magnus is given off as the obturator nerve passes through the substance of the muscle. (2) An **articular terminal branch** is supplied to the back of the knee-joint.

Anterior Crural Nerve.

The **anterior crural nerve** (n. femoralis) is the great nerve for the muscles and skin of the front of the thigh. It arises in the substance of the psoas muscle, from the back of the second, third, and fourth lumbar nerves, behind the obturator nerve. Passing obliquely through the psoas muscle, it emerges from its outer border in the false pelvis (Fig. 505, p. 641). Passing downwards in the groove between the psoas and iliacus, it enters the thigh beneath Poupart's ligament, external to the femoral sheath and femoral vessels. In Scarpa's triangle it breaks up into a large number of branches, among which the external circumflex artery passes.

The **branches** of the anterior crural nerve, which are (1) muscular, (2) articular, and (3) cutaneous, arise in the following way:—

In the abdomen a muscular branch arises from the outer side of the nerve and enters the iliacus muscle.

In Scarpa's triangle the terminal muscular, articular, and cutaneous branches arise in the form of a large bundle of nerves.

1. The **muscular branches** supply the pectineus, sartorius, and quadriceps extensor. The nerve to the *pectineus* arises close to Poupart's ligament, and coursing obliquely downwards and inwards behind the femoral vessels enters the muscle at its outer border. It is not infrequently double. It sometimes gives off a fine communicating branch to the superficial part of the obturator nerve. The nerves to the *sartorius* are in two sets: an outer short set of nerves associated with the outer part of the middle cutaneous nerve, which enter the upper part of the muscle; and an inner longer set which are associated with the inner part of the middle cutaneous nerve, and supply the middle of the muscle. The parts of the *quadriceps extensor* are supplied by several branches. The vastus externus and rectus femoris are supplied on their deep surface by separate nerves which are accompanied by branches of the external circumflex artery. The crureus muscle is supplied superficially by a nerve which passes through the muscle, and innervates also the subcrureus. It also receives fibres from one of

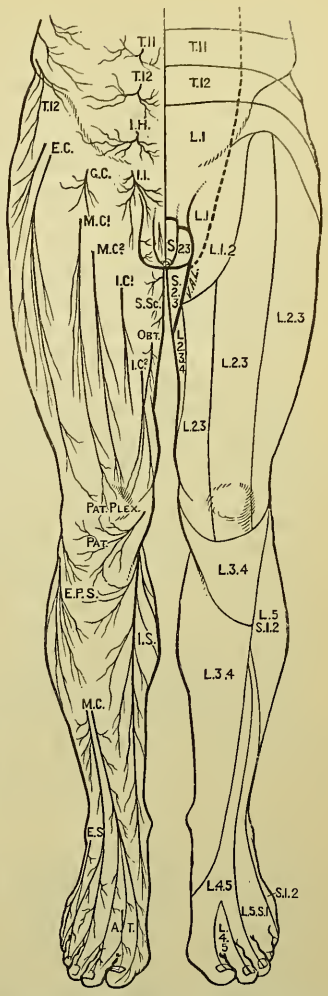


FIG. 507.—DISTRIBUTION OF CUTANEOUS NERVES ON THE FRONT OF THE LOWER LIMB.

On the one side the distribution of the several nerves is represented, the letters indicating their nomenclature.

T.11, Branches of eleventh thoracic nerve; T.12, Branches of twelfth thoracic nerve; I.H, Ilio-hypogastric; I.I, Ilio-inguinal; E.C, External cutaneous; G.C, Genito-crural; M.C¹,², Middle cutaneous; I.C¹,², Internal cutaneous; OBT, Obturator; S.Sc, Small sciatic; PAT. PLEX, Patellar plexus; PAT. Patellar branch of internal saphenous; E.P.S, Sural branches of peroneal nerve; I.S, Internal saphenous; M.C, Musculo-cutaneous; E.S, External saphenous; A.T, Anterior tibial.

On the other side a schematic representation is given of the areas supplied by the above nerves, the figures indicating the spinal origin of the branches of distribution to each area.

the nerves to the vastus internus. The vastus internus muscle is supplied by two nerves: an upper trunk, which supplies the higher part of the muscle, and sends fibres to the crureus as well; and a lower trunk, which descends on the outer side of the femoral artery along with the internal saphenous nerve, and passing beneath the sartorius, over or under the aponeurotic covering of Hunter's canal, enters the inner side of the vastus internus muscle. This nerve gives off a small branch which enters the medullary canal of the femur.

2. The **articular branches** supply the hip and knee-joints. The articular branch to the hip-joint arises from the nerve to the rectus femoris, and is accompanied by branches from the external circumflex artery. The articular branches to the knee-joint are four in number. Three of them arise from the nerves to the vastus externus, crureus, and vastus internus, which, after the muscular nerves are given off, are continued downwards to the knee-joint along the front of the femur. A fourth articular branch arises (sometimes) from the internal saphenous nerve.

3. The **cutaneous branches** are the middle and internal cutaneous, and the internal saphenous nerves (Fig. 507).

The **middle cutaneous nerve** arises in two parts, an *external* and an *internal branch*, in the upper part of Scarpa's triangle. The two branches descend vertically and become cutaneous by piercing the fascia lata over the upper third of the sartorius muscle. They carry muscular branches to the sartorius, and the external branch in many cases pierces the muscle. These two nerves supply the skin of the lower three-fourths of the front of the thigh, between the external cutaneous nerve on the outer side and the internal cutaneous on the inner side. They reach down to the front of the patella, and there assist in the formation of the patellar plexus. The external branch communicates in the upper third of the thigh with twigs from the crural branch of the genito-crural nerve.

The **internal cutaneous nerve** lies at first in Scarpa's triangle on the outer side of the femoral vessels. At the apex of the triangle it crosses over the femoral vessels, and is directed downwards over or through the sartorius muscle, and beneath the fascia lata, to the lower third of the thigh. It is distributed to the skin of the lower two-thirds of the thigh on the inner side by means of three branches—upper, middle, and lower.

The *upper branch* may be represented by two or more twigs. It arises from the main nerve near its origin, and pierces the fascia lata near the apex of Scarpa's triangle. It is distributed to the skin of the upper part of the thigh, along the line of the saphenous vein. The *middle* or *anterior branch* is a larger nerve. It separates from the lower branch at the apex of Scarpa's triangle, and passing over the sartorius muscle becomes cutaneous in the middle third of the thigh on the inner side. It supplies the skin of the lower half of the thigh on the inner side, extending as low as the knee, where it joins in the formation of the patellar plexus.

The *lower* or *internal branch* represents the termination of the nerve. It passes down the inner side of the thigh over the sartorius muscle, and communicates in the middle third of the thigh with the internal saphenous and obturator nerves to form the obturator plexus. Piercing the fascia lata on the inner side of the thigh in the lower third, it ramifies over the inner side of the knee, and assists in the formation of the patellar plexus.

The size of the internal cutaneous nerve varies with the size of the cutaneous part of the obturator, and of the internal saphenous nerve.

The **long** or **internal saphenous nerve** (n. saphenus) may be regarded as the terminal branch of the anterior crural nerve. It is destined for the skin of the leg and foot. From its origin in Scarpa's triangle it descends alongside the femoral vessels to Hunter's canal. In the canal it crosses over the femoral sheath from without inwards. At the lower end of the canal, accompanied by the superficial branch of the anastomotic artery, it passes over the tendon of the adductor magnus, and opposite the inner side of the knee-joint becomes cutaneous by passing between the sartorius and gracilis muscles. The nerve then extends down the leg along with the internal saphenous vein, and coursing over the front of the inner ankle it terminates at the middle of the inner border of the foot.

Branches.—1. A **communicating branch** arises in Hunter's canal, and passing

inwards beneath the sartorius joins with branches of the obturator nerve in forming the obturator plexus.

2. The **patellar branch** arises at the lower end of Hunter's canal, and piercing the sartorius muscle is directed downwards and forwards below the patella, and over the inner tuberosity of the tibia to the front of the knee and upper part of the leg. It enters into the formation of the patellar plexus.

3. An **articular branch** sometimes arises from the nerve at the inner side of the knee.

4. The **terminal branches** of the internal saphenous nerve are distributed to the skin of the front and inner side of the leg, and the posterior half of the dorsum and inner side of the foot.

Patellar plexus.—This plexus consists of fine communications beneath the skin in front of the knee, between the branches of the cutaneous nerves supplying that region. The nerves which enter into its formation are the patellar branch of the internal saphenous, internal and middle cutaneous nerves, and sometimes the external cutaneous nerve.

The **accessory obturator nerve** (n. obturatorius accessorius, n. accessorius anterioris cruralis Winslow) is only occasionally present (29 per cent, Eisler). It arises from the third, or third and fourth lumbar nerves, between the roots of the obturator and anterior crural nerves. Associating itself with the obturator, from which, however, it is quite separable, it appears in the abdomen at the inner side of the psoas muscle, and coursing over the pelvic brim behind the external iliac vessels, it leaves the obturator nerve, and enters the thigh in front of the pubis.

In the thigh, behind the femoral vessels, it usually ends in three branches: a nerve which replaces the branch from the anterior crural to the pectineus, a nerve to the hip-joint, and a nerve which communicates with the superficial part of the obturator nerve. In some cases it only supplies the nerve to the pectineus; more rarely it is of considerable size, and reinforces the obturator nerve in the innervation of the adductor muscles.

The accessory obturator nerve was first described by Winslow as the *n. accessorius anterioris cruralis*. Schmidt later described it in great detail, and gave it the name it now bears. It is more closely associated with the anterior crural than with the obturator. Its origin is behind the roots of the obturator: it is separated, like the anterior crural, from the obturator by the pubic bone, and its chief branch, to the pectineus muscle, replaces the normal branch from the anterior crural nerve. On the other hand, for a part of its course it accompanies the obturator, and in rare cases it may replace branches of that nerve.

THE SACRAL OR SCIATIC PLEXUS.

The sacral or sciatic portion of the lumbo-sacral plexus is destined almost entirely for the lower limb. It is usually formed by the anterior primary divisions of a part of the fourth lumbar nerve (n. furcalis), the fifth lumbar, the first, and parts of the second, and third sacral nerves (n. bigeminus).

Communications with the Sympathetic.—Each of the nerves named is connected to the lumbar or pelvic sympathetic by *gray rami communicantes*, as already described; and *white rami communicantes* pass usually from the third and usually also from the second or fourth sacral nerves to join the pelvic plexus of the sympathetic.

Position and Constitution.—The plexus is placed on the back wall of the pelvis between the parietal pelvic fascia and the pyriformis muscle. In front of it are the pelvic colon, the internal iliac vessels, and the ureter.

The plexus is constituted by the convergence of the nerves concerned towards the lower part of the great sacro-sciatic foramen, and their union to form a broad triangular band, the apex of which is continued through the great sacro-sciatic foramen below the pyriformis muscle into the buttock, as the **great sciatic nerve.** From the anterior and posterior surfaces of this triangular band numerous small branches arise, which are distributed to the parts in the neighbourhood of the origin of the nerve.

The great sciatic nerve ends in the thigh by dividing into two large nerves, the **tibial** (internal popliteal), and **peroneal** (external popliteal). In many cases these two nerves are distinct from their origin, and are separated sometimes by fibres of the pyriformis muscle. In all cases on removal of the sheath investing the great sciatic nerve the tibial and peroneal nerves can be traced up to the plexus, from which they invariably take origin by distinct and separate roots.

The descending branch of the fourth lumbar nerve (n. furcalis) after emerging from the inner border of the psoas muscle internal to the obturator nerve, divides

behind the iliac vessels into anterior and posterior (ventral and dorsal) parts, each of which joins a corresponding part of the fifth lumbar nerve. The anterior primary division of the fifth lumbar nerve descends over the ala of the sacrum, and divides into anterior and posterior parts, which are joined by the corresponding parts of the fourth lumbar nerve. The two resulting trunks are sometimes called the **lumbo-sacral cord.** The first and second sacral nerves pass almost horizontally outwards from the anterior sacral foramina, and divide in front of the pyriformis into similar anterior and posterior parts. The third sacral nerve (n. bigeminus) divides into upper and lower parts. The lower part is concerned in forming the pudendal plexus. The upper part is directed outwards, and slightly upwards, towards the preceding nerve, and does not separate into two parts, but remains undivided.

These trunks combine to form the sciatic or sacral plexus, and its main subdivisions, in the following way. Lying in apposition, and converging to the lower part of the great sacro-sciatic foramen, the *posterior* (dorsal) *trunks* of the fourth and fifth lumbar nerves (lumbo-sacral cord), and of the first and second sacral nerves, combine to form the **peroneal nerve** and the subordinate nerves which arise from the posterior aspect of the plexus. The *anterior* (ventral) *trunks* of the fourth and fifth lumbar nerves (lumbo-sacral cord), and of the first and second sacral nerves, together with that part of the third sacral nerve which is contributed to the plexus, unite to form the **tibial nerve** and the subordinate nerves arising from the front of the plexus.

Of these nerves the fifth lumbar and first sacral are the largest; the others diminishing in size as they are traced upwards and downwards. There is no distinct demarcation between the sacral and pudendal plexuses. The second and third sacral nerves (and in some cases the first sacral also) are concerned in the formation of both plexuses.

Branches.—The nerves of distribution derived from the sacral plexus are divided according to their origin into an *anterior* (ventral) and a *posterior* (dorsal) *series.* Each set comprises one of the two essential terminal parts—peroneal and tibial nerves—of the great sciatic, and numerous smaller collateral branches.

Anterior Branches.	Posterior Branches.
Tibial (internal popliteal) nerve	Peroneal (external popliteal) nerve
Muscular branches—	*Muscular branches*—
Nerves to hamstring muscles	Nerves to short head of biceps
,, quadratus femoris	,, pyriformis
,, gemelli	Superior gluteal nerve
,, obturator internus	Inferior gluteal nerve
Articular branches (to hip-joint)	*Articular branches* (to knee-joint)

Great Sciatic Nerve.

The **great sciatic nerve** (n. ischiadicus).—It has already been shown how this nerve is formed. It comprises the two main nerves of the sacral plexus, bound together by an investing sheath, which contains, in addition to the peroneal and tibial nerves, a subordinate branch of each, the nerve to the hamstring muscles, from the tibial, and the nerve to the short head of the biceps flexor cruris, from the peroneal nerve. A thick band about half an inch in breadth is formed, consisting from within outwards of (1) **nerves to the hamstring muscles,** (2) **tibial** (internal popliteal), (3) **peroneal** (external popliteal), (4) **nerve to the short head of the biceps muscle.** The great sciatic nerve extends through the buttock and the back of the thigh. Forming a continuation of the sacral plexus, it enters the buttock by passing through the great sacro-sciatic foramen, in the interval between the pyriformis and superior gemellus. Concealed by the gluteus maximus muscle, it passes downwards to the thigh, accompanied by the sciatic artery, and the arteria comes nervi ischiadici. It lies in the hollow between the great trochanter of the femur and the tuberosity of the ischium, and enters the thigh beneath the fold of the nates at the lower border of the gluteus maximus. At this spot it is comparatively superficial, lying in the angle between the edge of the gluteus maximus above and externally, and the origins of the hamstring muscles internally. In the thigh it is placed upon the adductor magnus beneath the hamstring muscles, and it terminates at a variable point by dividing into the tibial and peroneal nerves. As

already stated, these two nerves may be separate from their origins, and their separation may occur at any point between the great sacro-sciatic foramen and the upper part of the popliteal space.

The Nerves of Distribution from the Sacral Plexus.

These are divisible into two series—**collateral** and **terminal branches**. Each subdivision consists of a series of *anterior* (ventral) and *posterior* (dorsal) *trunks*.

Collateral Branches.—The *anterior branches* are (*a*) muscular branches (to the quadratus femoris, gemelli, obturator internus, and hamstring muscles); and (*b*) articular branches (to the hip-joint). These nerves all arise from the anterior aspect of the sacral plexus.

The **nerve to the quadratus femoris** (and **inferior gemellus**) arises from the front of the fourth and fifth lumbar and first sacral nerves. It passes downwards over the back of the capsule of the hip-joint (to which it sends a fine branch) beneath the sacral plexus, gemelli, and obturator internus muscles. It supplies a nerve to the inferior gemellus, and terminates in the deep surface of the quadratus femoris.

The **nerve to the obturator internus** (and **superior gemellus**) arises from the anterior aspect of the fifth lumbar and first two sacral nerves. In the buttock it lies below the great sciatic nerve on the outer side of the pudic vessels; crossing the ischial spine, it enters the ischio-rectal fossa through the lesser sciatic foramen. The nerve supplies in the buttock a branch to the superior gemellus, and terminates by entering the pelvic surface of the obturator internus.

The **nerve to the hamstring muscles** forms the innermost part of the great sciatic trunk in the lower part of the buttock. It arises from all the roots of the tibial nerve on their anterior aspect, viz., from the fourth and fifth lumbar and the first three sacral nerves. These roots unite to form a cord which is closely associated with the tibial nerve and is placed in front of and afterwards on its inner side. Extending into the thigh, the trunk is distributed to the hamstring muscles by means of two sets of branches. Just below the level of the ischial tuberosity an upper set of nerves passes inwards to enter the upper part of the semi-tendinosus and the ischial head of the biceps. Lower down in the thigh the remaining portion of the nerve separates off from the great sciatic (tibial) trunk and supplies branches to the semi-membranosus, the lower part of the semi-tendinosus, and the adductor magnus.

Articular branches for the hip-joint arise from the nerve to the quadratus femoris, and often directly from the front of the great sciatic (tibial) nerve near its origin. They enter the back of the capsule of the joint in the region of the buttock.

The *posterior branches* are: (*a*) muscular branches, viz. a nerve to the pyriformis, the superior gluteal nerve, the inferior gluteal nerve, and a nerve to the short head of the biceps; (*b*) articular branches (to the knee-joint).

These nerves all arise from the posterior aspect of those roots of the sacral plexus, which are associated with the origin of the peroneal nerve.

The **nerve to the pyriformis muscle** may be double. It arises from the back of the second, or first and second sacral nerves, and at once enters the anterior surface of the muscle.

The **superior gluteal nerve** (n. glutæus superior) arises from the back of the fourth and fifth lumbar and first sacral nerves, and is directed backwards and outwards into the buttock, above the pyriformis muscle, along with the gluteal artery. Under cover of the gluteus maximus and gluteus medius, it extends outwards over the gluteus minimus, along with the inferior part of the deep gluteal artery, to the under surface of the tensor vaginæ femoris, in which it ends. On its way it supplies branches to the gluteus medius and gluteus minimus.

The **inferior gluteal nerve** (n. glutæus inferior) arises from the back of the fifth lumbar and first two sacral nerves. It appears in the buttock at the lower border of the pyriformis muscle, superficial to the great sciatic nerve, and at once breaks up into a number of branches for the supply of the gluteus maximus. In its course in the buttock it is closely associated with the small sciatic nerve. Its origin is sometimes combined with that of the following nerve.

The **nerve to the short head of the biceps** springs from the outer side of the

great sciatic (peroneal) trunk in the upper part of the thigh. When traced to its origin, it is found to arise (sometimes in combination with the inferior gluteal nerve) from the fifth lumbar and first two sacral nerves. In its course it is closely applied to the outer side of the peroneal nerve, from which it separates in the middle third of the thigh, usually in combination with the articular branches of that nerve for the knee-joint. In some cases it has an independent course in the thigh, and it may be associated in the buttock with the inferior gluteal nerve.

An **articular branch** for the outer side and front of the knee-joint generally arises from the great sciatic or peroneal nerve in common with the nerve to the short head of the biceps. When traced up to the plexus, it is found to arise from the back of the fourth and fifth lumbar and first sacral nerves. It passes through the upper part of the popliteal space concealed by the biceps muscle, and separates into upper and lower branches, which accompany the upper and lower external articular arteries to the outer side of the knee-joint.

Terminal Branches.—The **peroneal** (external popliteal) and **tibial** (internal popliteal) **nerves** are the two main trunks resulting from the combination of the posterior and anterior cords respectively of the sacral plexus. The peroneal nerve is homologous with the musculo-spiral nerve in the upper limb; the tibial nerve represents a medio-ulnar trunk; and, as already stated, the two nerves, constituting the great sciatic nerve, are enveloped in a common sheath for a variable distance before pursuing an independent course in the leg.

Peroneal Nerve.

The **peroneal** or **external popliteal nerve** (n. peronæus communis) arises from the back of the sacral plexus from the fourth and fifth lumbar and first two sacral nerves. Incorporated with the great sciatic nerve in the buttock and upper half of the thigh, it passes downwards from the bifurcation of that nerve through the popliteal space, to its termination at a point about an inch below the head of the fibula. It is concealed at first by the biceps muscle. Following the tendon of that muscle, it passes obliquely through the upper and outer part of the popliteal space and over the outer head of the gastrocnemius muscle to the back of the head of the fibula. In the lower part of its course and at its termination it is directly beneath the deep fascia.

Collateral Branches.—These are divided into two sets: (*a*) Nerves arising from the roots or trunk of the nerve while it is in combination with the tibial nerve in the great sciatic trunk. These have been already described, viz. a **muscular branch** to the short head of the biceps, and an **articular branch** to the knee-joint. (*b*) Nerves arising in the popliteal space. These are **cutaneous branches**, viz. a sural branch and the peroneal communicating.

The **sural branch** (n. cutaneus suræ lateralis) is irregular in size and distribution, and may be represented by two or more branches (Fig. 507, p. 645). Arising from the peroneal nerve in the popliteal space, often in common with the succeeding nerve, it pierces the deep fascia over the outer head of the gastrocnemius, and is distributed to the skin on the outer aspect of the back of the leg in the upper two-thirds. The extent of its distribution varies with that of the small sciatic and external saphenous nerves.

The **peroneal communicating nerve** (r. anastomoticus peronæus, r. communicans fibularis), arising in the popliteal space, passes over the outer head of the gastrocnemius beneath the deep fascia to the middle third of the leg, where it assists in forming the external saphenous nerve by its union with the tibial communicating branch of the tibial nerve. In many cases the two branches do not unite. In such cases the peroneal communicating nerve may be limited in its distribution to the skin of the outer side of the leg, heel, and ankle, or it may be distributed to the area usually supplied by the external saphenous nerve.

Terminal Branches.—The terminal branches of the peroneal nerve are recurrent tibial, anterior tibial, and musculo-cutaneous. They arise just below the head of the fibula, and are directed forwards, diverging in their course, beneath the peroneus longus muscle.

The **recurrent tibial nerve** is the smallest branch. Passing forwards beneath

the origin of the peroneus longus and the extensor longus digitorum muscles, it divides below the outer tuberosity of the tibia into branches which supply the upper fibres of the tibialis anticus muscle, the tibio-fibular articulation, and the knee-joint.

Anterior Tibial Nerve.

The **anterior tibial nerve** (n. peronæus profundus) passes downwards and inwards, beneath the peroneus longus, extensor longus digitorum, and extensor proprius hallucis muscles, to the front of the leg. In its course down the leg it is deeply placed upon the interosseous membrane and the lower part of the tibia, in company with the anterior tibial artery. At the ankle it lies beneath the anterior annular ligament and the tendon of the extensor proprius hallucis, and crossing over the ankle-joint, it divides on the dorsum of the foot into its terminal branches.

1. **Collateral Branches** (in the leg).—These are given off to the muscles between which the anterior tibial nerve passes: tibialis anticus, extensor proprius hallucis, extensor longus digitorum, and peroneus tertius. A fine articular branch supplies the ankle-joint.

2. **Terminal Branches** (on the foot).—The terminal branches are internal and external. The **internal branch** passes along the dorsum of the foot on the outer side of the dorsalis pedis artery to the first interosseous space, where it divides into two dorsal digital branches for the supply of the skin of the outer side of the great toe and the inner side of the second toe. Each of these branches communicates with branches of the musculo-cutaneous nerve. It gives off one or two *dorsal interosseous branches,* which supply the inner tarso-metatarsal and metatarso-phalangeal articulations, and also enter the first dorsal interosseous muscle.

The **external branch** passes outwards over the tarsus beneath the extensor brevis digitorum, and ends in a gangliform enlargement (similar to the gangliform enlargement on the posterior interosseous nerve at the back of the wrist). From this enlargement muscular branches arise for the supply of the extensor brevis digitorum, along with branches for the tarsal, tarso-metatarsal, and metatarso-phalangeal articulations. Its *dorsal interosseous branches* may be as many as four in number. Of these the outer two, extremely small, may only reach the tarso-metatarsal articulations. The inner two are fine branches, which, besides supplying the articulations, may give branches to the second and third dorsal interosseous muscles.

The branches from the anterior tibial nerve to the interosseous muscles are probably sensory, the motor supply of these muscles being certainly derived from the external plantar nerve.

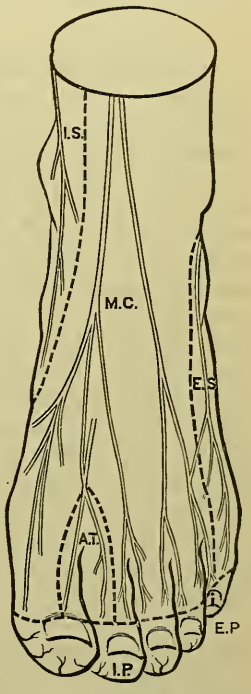


Fig. 508.—Distribution of Cutaneous Nerves on the Dorsum of the Foot.

I.S, Internal saphenous nerve; M.C, Musculo-cutaneous nerve; A.T, Anterior tibial nerve; E.S, External saphenous nerve. The extremities of the toes are supplied by the plantar nerves (I.P, E.P).

Musculo-Cutaneous Nerve.

The **musculo-cutaneous nerve** (n. peronæus superficialis), the last of the branches of the peroneal nerve, passes below the head of the fibula and beneath the upper fibres of the peroneus longus muscle. Lying in a sheath in the intermuscular septum, between the peronei externally and the extensor longus digitorum internally, it proceeds downwards in front of the fibula to the lower third of the leg, where it pierces the deep fascia in two branches, internal and external.

Its branches are: (1) collateral muscular branches distributed to the peroneus longus and peroneus brevis, as the nerve lies in relation to these muscles; (2) terminal cutaneous branches, internal and external.

The **internal terminal branch** courses downwards over the anterior annular liga-

ment of the ankle, and after supplying offsets to the lower third of the leg and dorsum of the foot, divides into three branches. (1) The internal branch supplies the skin of the dorsum of the foot and the inner side of the great toe, and communicates with the internal saphenous nerve. (2) The intermediate branch passes to the interval between the great toe and the second, and divides into two branches which communicate with the internal branch of the anterior tibial nerve. (3) The external branch passes to the interval between the second and third toes, and divides into two digital branches to supply the adjacent sides of these toes.

The **external terminal branch** of the nerve descends over the anterior annular ligament, and after supplying branches to the lower part of the leg and the dorsum of the foot, divides into two parts, internal and external, which, passing to the intervals between the third and fourth, and fourth and fifth toes respectively, divide into dorsal digital branches for the adjacent sides of these toes. These branches communicate with offsets of the external saphenous nerve.

The arrangement of the cutaneous branches of the musculo-cutaneous is liable to considerable variation. The outer division of the nerve may be increased in size, and may supply the nerve to the adjacent sides of the second and third toes; or in other cases, it may be reduced in size, in which case the external saphenous nerve takes its place on the dorsum of the foot, often supplying as many as two and a half toes on the outer side.

The cutaneous nerves on the dorsum of the toes from the anterior tibial and musculo-cutaneous nerves are much smaller than the corresponding plantar digital nerves. They are reinforced on the dorsum of the terminal phalanges by twigs from the plantar nerves, which supply the tips of the toes and the nails.

Tibial Nerve.

The **tibial** or **internal popliteal nerve** (n. tibialis) arises from the front of the sacral plexus, usually from the fourth and fifth lumbar and first three sacral nerves (Fig. 511, p. 656). It is incorporated in the great sciatic trunk in the buttock and upper part of the thigh. At the bifurcation of the great sciatic nerve it passes onwards through the popliteal space and the back of the leg. The part of the nerve from its origin from the plexus or the bifurcation of the great sciatic nerve to the lower border of the popliteus muscle, is sometimes called **internal popliteal**; the part of the nerve in the back of the leg being then designated **posterior tibial.** The course of the nerve through the buttock and thigh has already been described (p. 648). In the popliteal space it is concealed at first by the semi-membranosus and other hamstring muscles. It crosses the popliteal vessels from without inwards, and is thereafter found upon the popliteus muscle, under cover of the gastrocnemius and plantaris. In the back of the leg, from the lower border of the popliteus muscle to the ankle, the tibial (or posterior tibial) nerve lies on the tibialis posticus muscle and the tibia, and, along with the posterior tibial vessels, occupies a sheath in the intermuscular septum separating the superficial and deep muscles of the back of the leg. In the upper part of the leg the nerve is internal to the vessels, but, crossing over them, it lies on their outer side in the lower portion of its course. It terminates beneath the internal annular ligament by dividing into the external and internal plantar nerves.

The **collateral branches** may be divided into three series arising respectively in the region of the thigh, the popliteal space, and the back of the leg:—

(a) *Branches arising from the Roots or Trunk of the Nerve while it is incorporated with the Great Sciatic Nerve.*—These have been already described, viz. **muscular branches** to the quadratus femoris, gemelli, obturator internus, and the hamstring muscles, and an **articular branch** to the hip-joint (Fig. 511, p. 656).

(b) *Branches arising in the Popliteal Space above the Knee-Joint.*—These are in three sets—articular, muscular, cutaneous.

1. The **articular branches** are slender nerves, variable in number. There are usually two, an *azygos* branch which pierces the posterior ligament of the knee-joint, and an *internal* branch, a long fine nerve which, crossing the popliteal vessels, descends on the inner side of the space to accompany the lower internal articular artery to the knee-joint. In its course it gives off a branch, often absent, which accompanies the upper internal articular artery.

2. The **muscular branches** are five in number. Nerves for the two heads of the gastrocnemius, and the plantaris enter these muscles at the borders of the popliteal

space. A nerve for the soleus enters the superficial surface of the muscle. A nerve for the popliteus muscle passes over the surface of that muscle, and after winding round its lower border, supplies it on its deep (anterior) surface. As this nerve passes beneath the popliteus it supplies branches to the tibialis posticus muscle, an interosseous branch for the interosseous membrane, which can be traced as far as the lower tibio-fibular articulation, an articular branch for the upper tibio-fibular joint, and a medullary branch for the shaft of the tibia.

3. The **cutaneous branch** is the **tibial communicating nerve** (n. communicans tibialis, n. cutaneus suræ medialis). This nerve passes from the popliteal space in the groove between the two heads of the gastrocnemius muscle, and afterwards lies upon the tendo achillis. It pierces the deep fascia in the middle third of the back of the leg, and is joined immediately afterwards by the peroneal communicating nerve from the peroneal nerve. From their union the **external** or **short saphenous nerve** results, which reaches the foot, winding round the back of the external malleolus along with the external saphenous vein. The external saphenous nerve supplies cutaneous branches to the outer side and back of the lower third of the leg, the ankle and heel, and the outer side of the foot and little toe, as well as articular branches to the ankle and tarsal joints.

The external saphenous nerve communicates on the foot with the musculo-cutaneous nerve, and its size varies with the size of that nerve. It may extend on to the dorsum of the foot for a considerable distance, and may either reinforce or replace the branches of the musculo-cutaneous nerve to the intervals between the fourth and fifth and the third and fourth toes. The mode of formation of the external saphenous nerve is very variable. The usual arrangement is that described. Frequently the peroneal and tibial communicating nerves do not unite, and in such cases the more usual arrangement is for the tibial communicating nerve to form alone the external saphenous nerve, the peroneal communicating nerve extending only to the ankle and heel. It is less usual for the peroneal communicating nerve to form alone the external saphenous nerve, the tibial communicating nerve in these cases ending at the heel.

(c) *Branches arising in the Back of the Leg below the Knee-Joint.*—These branches are mainly muscular and cutaneous.

The **muscular branches** are four in number, comprising nerves to the soleus (entering its deep surface) and tibialis posticus, often arising by a common trunk, and nerves to the flexor longus digitorum and flexor longus hallucis, the latter generally accompanying the peroneal artery for some distance.

The **cutaneous branch** is the **internal calcanean nerve** (rr. calcanei mediales), which pierces the internal annular ligament, and is distributed to the skin of the heel and back part of the sole of the foot.

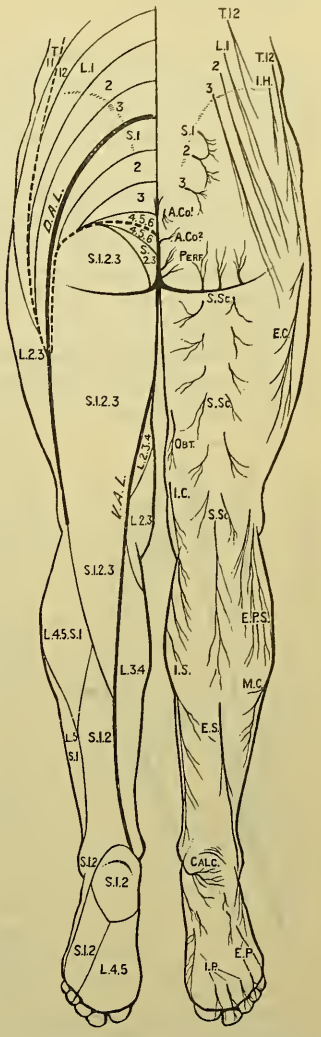


FIG. 509.—DISTRIBUTION OF CUTANEOUS NERVES ON THE BACK OF THE LOWER LIMB.

On the one side the distribution of the several nerves is represented, the letters indicating their nomenclature.

L. 1, 2, 3, S. 1, 2, 3, Posterior primary divisions of lumbar and sacral nerves; I.H, Ilio-hypogastric; T.12, Lateral and posterior branches of last thoracic nerve; A.Co¹, Posterior sacro-coccygeal nerve; A.Co², Anterior sacro-coccygeal nerve; PERF, Perforating cutaneous nerve; S.Sc, Small sciatic; E.C, External cutaneous; OBT, Obturator; I.C, Internal cutaneous; E.P.S, Sural branches of peroneal; I.S, Internal saphenous; E.S, External saphenous; M.C, Musculo-cutaneous; CALC, Calcanean branch of posterior tibial; I.P, Internal plantar; E.P, External plantar nerve.

On the other side a schematic representation is given of the areas supplied by the above nerves, the figures indicating the spinal origin of the branches of distribution to each area.

In addition a medullary nerve to the fibula, and a small articular branch to the ankle-joint, are supplied by the posterior tibial nerve.

The **terminal branches of the tibial nerve** are the internal and external plantar nerves.

Internal Plantar Nerve.

The **internal plantar nerve** (n. plantaris medialis) is homologous with the median nerve in the hand (Fig. 510, p. 654). It is rather larger than the external plantar. It courses forwards in the sole of the foot beneath the internal annular ligament and abductor hallucis to the interval between that muscle and the flexor brevis digitorum, in company with the internal plantar artery.

The **collateral branches** are muscular, cutaneous, and articular. The *muscular* branches supply the abductor hallucis and the flexor brevis digitorum. The plantar *cutaneous* branches are small twigs which pierce the plantar fascia in the interval between these muscles to supply the inner part of the sole of the foot. The *articular* branches are minute twigs which supply the inner tarsal and tarso-metatarsal articulations.

The **terminal branches** are four in number, and may be designated first, second, third, and fourth, from within outwards.

The **first** (most internal) branch separates from the nerve before the others, and pierces the plantar fascia behind the ball of the great toe. It supplies a muscular branch to the flexor brevis hallucis, and cutaneous branches to the inner side of the foot and ball of the great toe. It terminates as the plantar digital nerve for the inner side of the great toe.

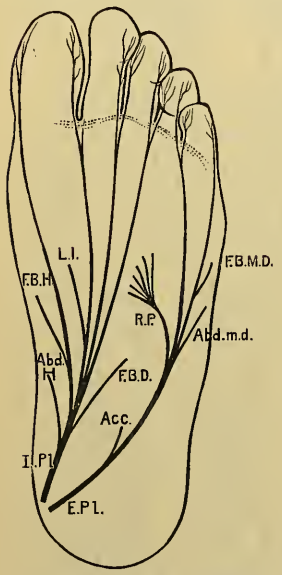


Fig. 510.—Scheme of Distribution of the Plantar Nerves.

I.Pl, Internal plantar nerve, and its cutaneous and muscular branches; F.B.D, Flexor brevis digitorum; Abd.H, Abductor hallucis; F.B.H, Flexor brevis hallucis; L.I, First lumbricalis; E.Pl, External plantar nerve, and its cutaneous and muscular branches; Acc, Accessorius; Abd.m.d, Abductor minimi digiti; F.B.M.D, Flexor brevis minimi digiti; R.P, Ramus profundus.

The **second branch** arises along with the third and fourth; after supplying a branch to the first lumbrical muscle, it becomes superficial in the interval between the first and second toes, and terminates by dividing into two collateral digital nerves for the supply of the adjacent sides of these toes.

The **third** and **fourth branches** are entirely cutaneous in their distribution. They become superficial in the intervals between the second and third and the third and fourth toes respectively, and there divide into collateral digital branches for the supply of the adjacent sides of these toes.

The **plantar digital nerves** supply the whole length of the toes on the plantar aspect, and, in relation to the terminal phalanges, furnish minute dorsal offsets for the supply of the nails and tips of the toes on their dorsal surface. The internal plantar nerve thus supplies the skin of the three and a half inner toes in the sole of the foot; and four muscles:—the abductor hallucis and flexor brevis digitorum, the flexor brevis hallucis, and the first lumbrical muscle.

External Plantar Nerve.

The **external plantar nerve** (n. plantaris lateralis) is homologous with the ulnar nerve in the hand. From its origin beneath the internal annular ligament it extends forwards and outwards in the sole, in company with the external plantar artery, between the flexor brevis digitorum and accessorius muscles, towards the head of the fifth metatarsal bone. Here it terminates by dividing into superficial and deep branches.

Collateral Branches.—*Muscular branches* are given off from the undivided nerve to the accessorius and abductor minimi digiti muscles. *Cutaneous branches* pierce the plantar fascia at intervals along the line of the intermuscular septum, between the flexor brevis digitorum and abductor minimi digiti.

Terminal Branches.—The **superficial branch** (r. superficialis) is mainly cutaneous.

Passing forwards between the flexor brevis digitorum and abductor minimi digiti, it divides into external and internal parts.

The *external branch*, after supplying the flexor brevis minimi digiti muscle, and sometimes one or both interossei of the fourth space, becomes superficial behind the ball of the little toe, and supplies cutaneous twigs to the sole of the foot and ball of the toe. It terminates as the digital branch for the outer side of the little toe.

The *internal branch* passes forwards to the interval between the fourth and fifth toes, where it becomes cutaneous, and divides into two collateral digital branches for the supply of the adjacent sides of these toes. It communicates with the fourth terminal branch of the internal plantar nerve.

The **deep branch** (r. profundus) of the external plantar nerve, passing deeply along with the external plantar artery, extends inwards towards the great toe, beneath the accessorius and adductor obliquus hallucis. It gives off *articular branches* to the tarsal and tarso-metatarsal articulations, and *muscular branches* to the interossei of each space (except in some cases the muscles of the fourth space): to the adductor obliquus and adductor transversus hallucis, and the outer three lumbrical muscles. These nerves enter the deep surface of the muscles, that to the second lumbrical reaching its muscle after passing forwards beneath the adductor transversus hallucis.

THE PUDENDAL PLEXUS.

The pudendal plexus constitutes the third and last subdivision of the lumbo-sacral plexus. It is composed for the most part of the spinal nerves below those which form the sacral plexus; but, as already stated, there is no distinct point of separation between the two plexuses. On the contrary, there is considerable overlapping, so that two and sometimes three of the principal nerves derived from the pudendal plexus have their origin in common with nerves of the sacral plexus.

The plexus is formed by fibres from the anterior primary divisions of the first three sacral nerves, and by the whole of the anterior primary divisions of the fourth and fifth sacral and coccygeal nerves. The size of the nerves diminishes rapidly from the first sacral to the coccygeal, which is extremely slender.

Position and Constitution.—The plexus is formed on the back wall of the pelvis. Of the nerves forming it, the upper ones emerge from the anterior sacral foramina; the fifth sacral nerve appears between the last sacral and first coccygeal vertebra; and the coccygeal nerve appears below the transverse process of that vertebra. The nerves of distribution derived from the plexus are the following:—

1. Visceral branches.
2. Small sciatic nerve.
3. Perforating cutaneous nerve.
4. Pudic nerve.
5. Muscular branches.
6. Sacro-coccygeal nerve.

Omitting the visceral branches, all the nerves are distributed to the perineum. Only two, the small sciatic and perforating cutaneous nerves, send branches to the lower limb.

Visceral Branches.—Like the other spinal nerves, the fourth and fifth sacral and coccygeal nerves are provided with fine *gray rami communicantes* from the sacral gangliated cord, which joins them after a short course on the front of the sacrum. The third (along with the second or fourth) sacral nerve in addition sends a considerable *white ramus communicans* or **visceral branch** inwards to the pelvic plexus and viscera.

Small Sciatic Nerve (n. cutaneus femoris posterior).—This nerve is complex both in origin and distribution (Fig. 511, p. 656). Springing from the junction of the sacral and pudendal plexuses, it is derived from the first three or second and third sacral nerves. It is distributed to the lower limb and perineum, and is associated with other nerves belonging to both regions. It arises from the back of the roots of the sacral plexus in the pelvis. Its higher roots from the first and second sacral nerves are intimately associated with the origin of the inferior gluteal nerve; its lowest root from the third sacral nerve is associated with the origins of the perforating cutaneous or pudic nerve. It enters the buttock through the great sciatic notch below the pyriformis, along with the sciatic artery and inferior gluteal

nerve. Proceeding downwards behind the great sciatic nerve, it enters the thigh at the lower border of the gluteus maximus muscle, where it gives off considerable branches. Becoming gradually smaller as it courses downwards over the hamstring

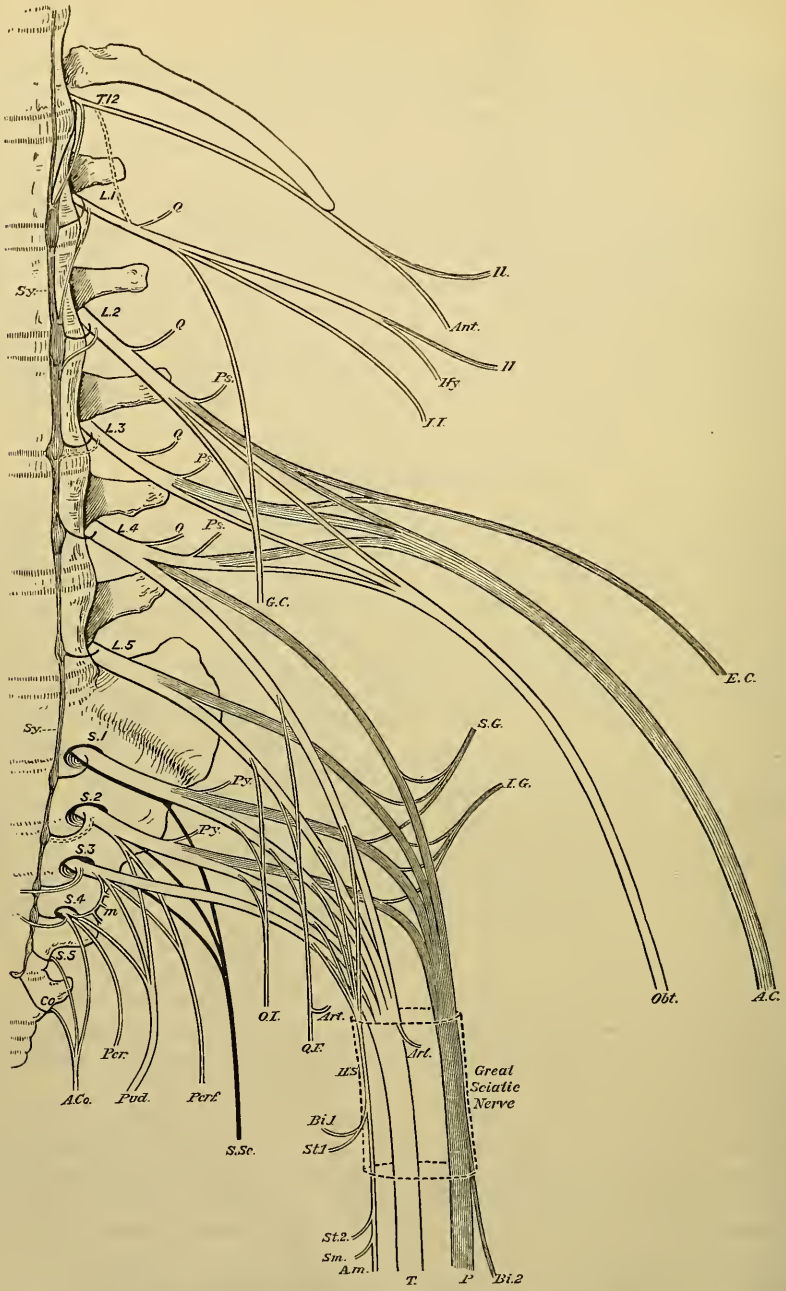


FIG. 511.—NERVES OF THE LUMBO-SACRAL PLEXUS.

Sy, Sympathetic cord; T.12, L.1, 2, 3, 4, 5, S.1, 2, 3, 4, 5, Co, Anterior primary divisions of the last thoracic, the lumbar, sacral, and coccygeal nerves; Q, Nerves to quadratus lumborum; Ps, Nerves to psoas muscle; G.C, Genito-crural nerve; Il, Iliac branches of last thoracic and ilio-hypogastric nerves; Hy, Hypograstic branch of ilio-hypogastric nerve; I.I, Ilio-inguinal nerve; E.C, External cutaneous nerve; A.C, Anterior crural nerve; Obt, Obturator nerve; Py, Nerves to pyriformis muscle; O.I, Nerve to obturator internus; Q.F, Nerve to qnadratus femoris muscle; Art, Articular branch; S.G, Superior gluteal nerve; I.G. Inferior gluteal nerve; P, Peroneal nerve; Bi.2, Nerve to short head of biceps muscle; T, Tibial nerve; Art, Articular branch; H.S, Nerve to the hamstring muscles; Bi.1, Nerves to biceps (long head), and St.1, to semi-tendinosus; St.2, Semi-tendinosus; Sm, Semi-membranosus; A.m, Adductor magnus; S.Sc, Small sciatic nerve; Perf, Perforating cutaneous nerve; Pud, Pudic nerve; M, Muscular branches; Per, Perineal branch of fourth sacral; A.Co, Anterior sacro-coccygeal nerve.

muscles to the popliteal space, it finally pierces the popliteal fascia in one or more cutaneous branches, which supply the skin over the calf of the leg for a variable distance (Fig. 509, p. 653).

Branches.—The small sciatic is a purely cutaneous nerve. It supplies branches to the perineum, buttock, thigh, and leg.

The **perineal branch** (rr. perinæales; inferior pudendal nerve; long scrotal nerve) arises from the small sciatic nerve at the lower border of the gluteus maximus muscle (Fig. 512, p. 658). It sweeps inwards towards the perineum, lying on the origin of the hamstring muscles below the ischial tuberosity, and becomes subcutaneous after passing over the pubic arch. Its terminal branches supply the skin of the scrotum and root of the penis, or in the female the labium majus and clitoris, some of them being directed backwards towards the anus and central point of the perineum. They communicate with the inferior hæmorrhoidal and perineal branches of the pudic nerve, and with the ilio-inguinal nerve. In its course to the perineum the nerve gives off *collateral branches* to the skin of the upper and inner part of the thigh.

The **gluteal branches** (rr. clunium inferiores) are large and numerous (Fig. 509, p. 653). They arise from the small sciatic nerve beneath the gluteus maximus, and become subcutaneous by piercing the fascia lata at different points along its lower border. They supply the skin of the lower half of the buttock. The outermost branches, reaching to the back of the great trochanter, overlap the terminal filaments of the gluteal branches of the external cutaneous nerve, and the posterior primary divisions of the first three lumbar nerves. The innermost branches, which may pierce the great sacro-sciatic ligament, reach nearly to the coccyx, and are co-terminous in their distribution with the branches of the perforating cutaneous nerve, which they reinforce and not infrequently replace.

The **femoral branches** are divisible into two sets—*internal* and *external*. They pierce the fascia lata of the thigh at intervals, and supply the skin of the back of the thigh on its inner and outer sides respectively.

The **sural branches** are two or more slender nerves which pierce the fascia over the popliteal space, and are distributed for a variable extent to the skin of the back of the leg. They may stop short over the popliteal space, or may extend as far as the ankle. Usually they innervate the skin as far as the middle of the calf. They communicate with the external saphenous nerve.

In cases where the great sciatic nerve is naturally divided at its origin into tibial (internal popliteal) and peroneal (external popliteal) nerves (*e.g.* by the pyriformis muscle), the small sciatic nerve is also separated into two parts: a **dorsal part,** associated with the peroneal nerve and arising in common with the lower roots of the inferior gluteal nerve (usually from the first and second sacral nerves), and comprising the gluteal and external femoral branches; and a **ventral part,** associated with the tibial nerve and arising usually from the second and third sacral nerves, along with the perforating cutaneous and pudic nerves, and comprising the perineal and internal femoral branches.

Perforating Cutaneous Nerve (n. perforans ligamenti tuberoso-sacri (Schwalbe), n. cutaneus clunium inferior medialis (Eisler)).—This nerve arises from the back of the second and third sacral nerves (Fig. 512, p. 658). At its origin it is associated with the lower roots of the small sciatic nerve. Passing downwards it pierces the great sacro-sciatic ligament, along with the coccygeal branch of the sciatic artery; and after winding round the lower border of the gluteus maximus muscle, or in some cases piercing its lower fibres, it becomes subcutaneous a little distance from the coccyx, and supplies the skin over the lower part of the buttock and the inner part of the fold of the nates.

The perforating cutaneous nerve is not always present. In a minority of cases it is associated at its origin with the pudic nerve. When absent as a separate nerve, its place is taken by (1) gluteal branches of the small sciatic nerve, or (2) a branch from the pudic nerve, or (3) a small nerve (n. perforans coccygeus major, Eisler), arising separately from the back of the third and fourth sacral nerves.

Muscular Branches.—Between the third and fourth sacral nerves (occasionally reinforced by the second, Eisler) a plexiform loop is formed, from which muscular nerves are given off to the levator ani (supplying the muscle on its pelvic surface), coccygeus, and external sphincter. The nerve to the external sphincter

(*perineal branch of fourth sacral*) pierces the great sacro-sciatic ligament and the coccygeus muscle, to which it gives offsets, and appears in the ischio-rectal fossa between the gluteus maximus and the external sphincter. Besides supplying the posterior fibres of the external sphincter, it distributes cutaneous offsets to the skin of the ischio-rectal fossa and the fold of the nates behind the anus. This nerve replaces in some instances the perforating cutaneous nerve.

Anterior Sacro-coccygeal Nerves (nn. ano-coccygei).—By the union of the remaining part of the fourth with the fifth sacral and coccygeal nerves, the so-called **coccygeal plexus** is formed. A fine descending branch of the fourth sacral nerve passes over or through the great sacro-sciatic ligament, to join the fifth sacral nerve. This fifth sacral nerve, joined by the descending branch of the fourth, descends alongside the coccyx and is again joined by the coccygeal nerve, so that a plexiform cord results, homologous with the inferior caudal trunk of tailed animals. Fine twigs arise from it, which pierce the sacro-sciatic ligament and supply the skin in the neighbourhood of the coccyx, internal to the perforating cutaneous nerves and behind the anus.

The Pudic Nerve.

The **pudic nerve** (n. pudendus) is the principal nerve for the supply of the perineum. It arises in the pelvis usually by three roots from the second, third, and

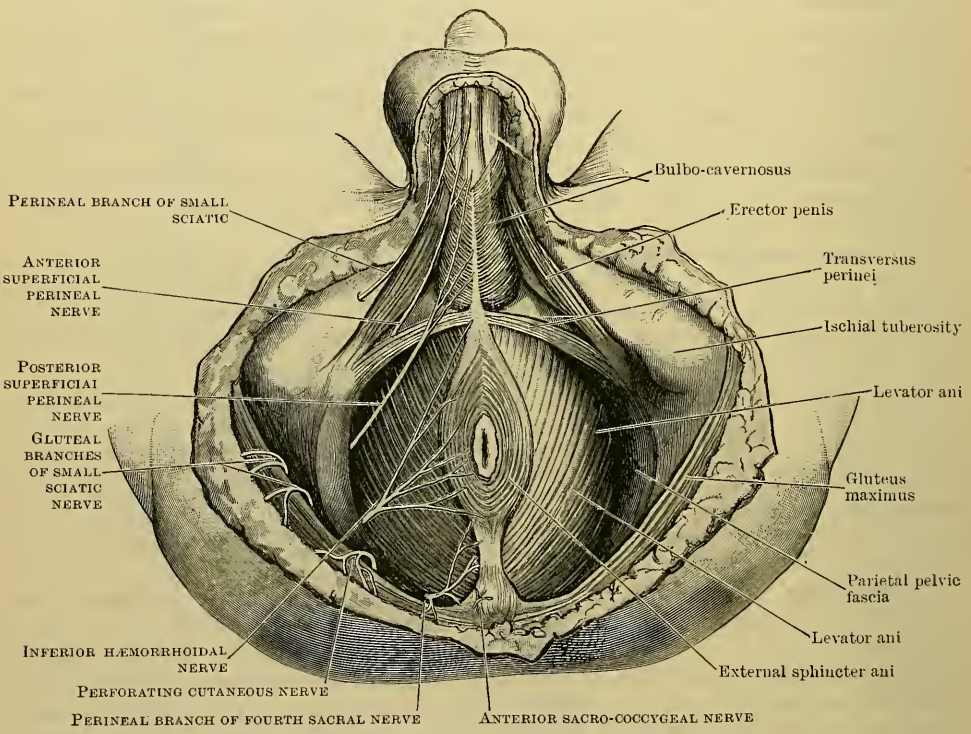


Fig. 512.—The Muscles and Nerves of the Male Perineum.

fourth sacral nerves (Fig. 511, p. 656). (Frequently one of its branches, the inferior hæmorrhoidal nerve, arises independently from the third and fourth sacral nerves). The nerve passes to the buttock through the great sacro-sciatic foramen below the great sciatic nerve, and lies on the lesser sacro-sciatic ligament, or the spine of the ischium, internal to the internal pudic artery. It enters the perineum along with the pudic artery through the small sacro-sciatic foramen. In the perineum it is deeply placed in the outer wall of the ischio-rectal fossa, enclosed in a special sheath derived from the parietal pelvic fascia covering the inner surface of the obturator internus muscle. At the anterior limit of the ischio-rectal fossa, the nerve approaches the surface and divides at the base of the triangular ligament into its terminal branches, the perineal nerve and the dorsal nerve of the penis.

The branches of the pudic nerve are essentially the same in the two sexes. As a rule no branches are given off till the nerve enters the perineum, but sometimes the inferior hæmorrhoidal nerve has an independent origin from the plexus, merely accompanying the pudic nerve in the first part of its course; and in exceptional cases the perforating cutaneous nerve of the buttock is a branch of the pudic nerve.

The **inferior hæmorrhoidal nerve** (n. hæmorrhoidalis inferior) arises from the pudic nerve under cover of the gluteus maximus, at the posterior part of the ischio-rectal fossa. In cases in which it has an independent origin from the plexus, it arises from the third and fourth sacral nerves. It crosses the ischio-rectal fossa in company with the inferior hæmorrhoidal vessels, and separates into numerous branches—muscular, cutaneous, and communicating.

The **muscular branches** end in the external sphincter ani muscle. The **cutaneous branches** supply the skin around the anus. The **communicating branches** connect the inferior hæmorrhoidal with three other nerves—the perineal branches of the small sciatic, pudic, and fourth sacral nerves.

The **perineal nerve** (n. perineus), one of the two terminal branches of the pudic nerve, arises near the base of the triangular ligament. It almost immediately divides into two parts, superficial and deep.

The **superficial part** is purely cutaneous and consists of two nerves, the posterior

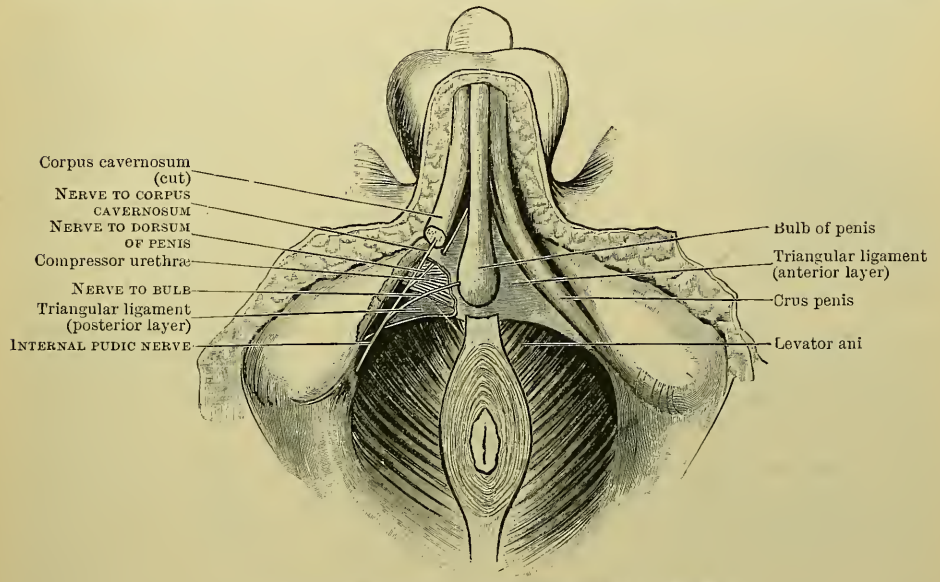


Fig. 513.—The Triangular Ligament of the Perineum.

or external and the anterior or internal superficial perineal nerves, which pass, along with the superficial perineal vessels, to the anterior part of the perineum. The **posterior or external superficial perineal nerve**, at the anterior limit of the ischio-rectal fossa, usually passes over the base of the triangular ligament and over the transversus perinei muscle. The **anterior or internal superficial perineal nerve**, lying more deeply, pierces the base of the triangular ligament and goes underneath or through the transversus perinei muscle. Becoming superficial in the anterior (urethral) triangle of the perineum, they are distributed to the skin of the scrotum (or labium majus), and communicate with the perineal branch of the small sciatic nerve and with the inferior hæmorrhoidal nerve.

The **deep part** of the perineal nerve is mainly but not entirely muscular. Coursing forwards through the anterior part of the ischio-rectal fossa, it passes between the two layers of the triangular ligament towards the urethra. It supplies muscular branches to the anterior parts of the levator ani and external sphincter, to the transversus perinei, erector penis (or clitoridis), bulbo-cavernosus (ejaculator urinæ or sphincter vaginæ), and compressor urethræ. It terminates as the nerve to the bulb, which, piercing the triangular ligament, enters the bulb of the urethra

and supplies the erectile tissue of the bulb and corpus spongiosum, as well as the mucous membrane of the urethra as far as the glans penis (or clitoridis).

The **dorsal nerve of the penis**, the other terminal branch of the pudic nerve, accompanies the internal pudic artery beneath the superficial layer of the triangular ligament. It passes forward close to the pubic arch, lying beneath the crus and erector penis (or clitoridis), and triangular ligament, and upon the compressor urethræ muscle; piercing the triangular ligament near its apex, at the outer side of the dorsal artery of the penis (or clitoris), it passes on to the dorsum of the penis or clitoris, to which it is distributed in its distal two-thirds, sending branches round the sides of the organ to reach its under surface. In the female the nerve is much smaller than in the male. The dorsal nerve of the penis supplies one branch, the **nerve to the corpus cavernosum**, as it lies beneath the triangular ligament. This is a slender nerve, which, piercing the triangular ligament, supplies the erectile tissue of the crus and corpus cavernosum.

Morphology of the Pudendal Plexus.—The structures occupying the perineum are placed in the ventral axis of the body, and comprise from before backwards, the penis and scrotum, or mons Veneris and vulva, the central point of the perineum, the anus and ischio-rectal fossa, and the coccyx. They are placed on the mesial side of the attachment of the lower limbs—the penis or mons Veneris in relation to the preaxial border; the coccyx in relation to the postaxial border of the limb.

The nerves of the perineum, thus reaching the ventral axis of the trunk, are homologous with the anterior (ventral) terminations of other nerves. They are separated into two series. Mainly supplied through the pudendal plexus by the last four sacral and the coccygeal nerves, the perineum is also innervated to a minor extent by the first lumbar nerve through the ilio-inguinal nerve, which reaches the root of the penis and the scrotum. The region is thus supplied by two series of widely separated nerves, which have their meeting-place on the dorsum and side of the penis and scrotum. This junction of the ilio-inguinal and pudendal nerves constitutes the beginning of the **ventral axial area or line**, which extends peripherally along the inner side of the lower limb. Apart from this break in their distribution, a definite numerical order may be followed in the arrangement of the perineal nerves. The higher parts of the perineum are innervated by the higher spinal nerves; the lower parts, by the lower nerves. This is best exemplified in the distribution of the cutaneous nerves. The base of the penis and scrotum (or mons Veneris) is supplied by the first lumbar nerve (ilio-inguinal). The dorsal nerve of the penis (or clitoris), when traced back to the pudendal plexus, is found to come from the second, and to a less extent from the third sacral nerves; the scrotal nerves (perineal branches of the pudic and small sciatic) similarly arise from the third, and to a less extent from the second sacral nerves; the skin of the ischio-rectal fossa and anus is innervated by the inferior hæmorrhoidal (third and fourth sacral nerves), and the perineal branch of the fourth sacral nerve. The coccygeal plexus, lastly, supplies the skin round the coccyx (fourth and fifth sacral and coccygeal nerves). Judged from its nerve supply the perineum is to be regarded as occupying, for the most part, a position behind or more caudal than that of the lower limb in relation to the trunk. There is here a remarkable gap in the numerical sequence of the nerves supplying the ventral axis of the body. All the nerves between the first lumbar and the second sacral fail to reach the mid ventral line of the trunk and are wholly concerned in the innervation of the lower limb.

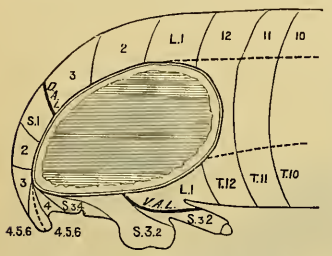


FIG. 514.—SCHEME of the innervation of the hinder portion of the trunk and of the perineum, and the interruption of the segmental arrangement of the nerves associated with the formation of the limb.

T.10, 11, 12, The areas of distribution of the lower thoracic nerves; L.1, 2, 3, The posterior primary divisions of the first three lumbar nerves; L.1, The ilio-inguinal nerve; S.1, 2, 3, 4, 5, 6, The posterior primary divisions of the sacral and coccygeal nerves (6); S.3, 2, S.3, 2, Branches of pudic nerve to penis and scrotum; S.3, 4, Inferior hæmorrhoidal nerve; 4, Perineal branch of the fourth sacral nerve; 4, 5, 6, Anterior sacro-coccygeal nerve; D.A.L, Dorsal axial line; V.A.L, Ventral axial line.

At the preaxial border of the limb (groin) the first lumbar nerve, the highest nerve supplying the perineum, is concerned also in innervating the skin of the limb. At the postaxial border of the limb (fold of the nates and back of the thigh), the nerves which are the highest of those constituting the pudendal plexus (the second and third sacral nerves) are also implicated in innervating that border of the limb. The fourth sacral nerve is only concerned to a very slight extent in the innervation of the limb by means of the perineal branch, which reaches the beginning of its postaxial border; the last two spinal nerves are wholly unrepresented in the limb proper and end entirely in the trunk behind the limb.

DEVELOPMENT OF THE SPINAL NERVES.

I. **Origin of the Spinal Nerve Roots.**—The process of development of the spinal

nerves commences by means of the outgrowth of the **dorsal** and **ventral roots** from the medullary tube. The two roots take origin in quite different ways.

The **dorsal root** is the first to appear,—before, during, or after the union of the medullary plates and the formation of the neural tube. It takes origin as a **cellular bud** from the dorsal surface of the medullary tube in one of three ways:—(1) It may arise from the junction of the medullary plate and surface epiblast before the closure of the medullary groove. (2) It may spring from the *neural crest*, a ridge on the dorsal aspect of the medullary tube, after its closure is complete. (3) It may be simply a direct outgrowth from the dorsal surface of the medullary tube. Pyriform in shape, the bud enlarges and becomes separated from the medullary tube, and projects ventrally in the space between the myotome and the medullary tube. Each bud is separated by only a slight interval from its neighbour.

The cells (**neuroblasts**) composing the bud become rapidly spindle-shaped, and by the middle of the fourth week give rise to *two sets of processes*; (1) a **central series**, which

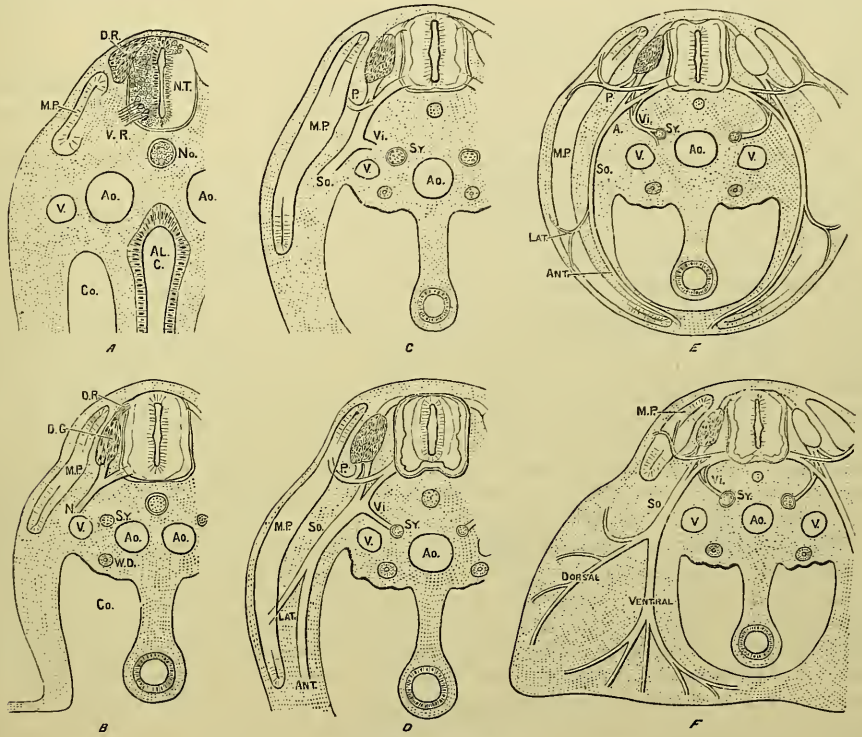


FIG. 515.—DEVELOPMENT OF THE SPINAL NERVES.

A, Formation of nerve roots.

D.R, Dorsal root.
V.R, Ventral root.
N.T, Neural tube.
No, Notochord.
Al.C, Alimentary canal.
Ao, Aorta.
V, Cardinal vein.
M.P, Muscle plate.

B, Formation of nerve trunk (N).

D.G, Dorsal ganglion.
Sy, Sympathetic cord.
W.D, Wolffian duct.
Co, Cœlom.

C, Formation of nerves.

So, Somatic division.
Vi, Visceral branch.
P, Posterior primary division.

D, E, Formation of subordinate branches.

Lat, Lateral, and
Ant, Anterior, branches.

F, Formation of nerve trunks in relation to the limb: dorsal and ventral trunks corresponding to lateral and anterior trunks in D and E.

grow backwards and are secondarily connected with the dorso-lateral aspect of the medullary tube as the fibres of the dorsal root; and (2) a **peripheral series**, which constitute the dorsal root fibres of the spinal nerve and join the ventral root, to form the spinal nerve proper. The intermediate cellular mass remains as the **spinal ganglion**.

The **ventral root** of a spinal nerve arises in quite a different way, from cells (**neuroblasts**) in the substance of the medullary tube. In the account of the development of the spinal cord it has been shown how the cellular constituents of the medullary tube are converted into two classes of cells: (1) **spongioblasts**, which produce the matrix (neuroglia) of the spinal cord; and (2) **germ-cells** or **neuroblasts**, which produce the nerve-cells of the gray matter of the cord. The neuroblasts give rise to the axis-cylinder processes or

axons, which, penetrating the spongy tissue of the medullary tube and the outer limiting membrane, find their way into the mesoblastic tissue on the ventro-lateral surface of the tube. Fibrous from their earliest origin and derived from nerve-cells which remain within the medullary tube, the axons of which the ventral root is composed become surrounded by mesoblastic cells immediately on their emergence, which give rise to the sheaths of the nerve. The ventral root is a little later in its date of appearance than the dorsal root. It begins to be evident at the twenty-fourth day and is completely formed by the twenty-eighth day.

II. **Formation of the Spinal Nerve.**—The fibres of the dorsal root ganglion and the ventral root grow by extension from the cells with which they are respectively connected, and meet in the space between the myotome and the side of the medullary tube to form the **spinal nerve**. It has been already shown that in the adult there is a fundamental division of the spinal nerve into posterior and anterior primary divisions. In the process of development this separation is even more obvious. As the fibres of the dorsal and ventral roots approximate, they separate at the same time each into two unequal portions: the smaller parts of the two roots unite together to form the **posterior**, and the larger parts unite to form the **anterior primary division** of the spinal nerve.

The **posterior primary division**, curving outwards and dorsally, passes through the myotome and is connected with it. In the substance of the myotome it separates into branches as it proceeds towards the dorsal wall of the embryo. At a later stage, the branches are definitely arranged into an outer and an inner set.

The **anterior primary division** grows gradually in a ventral direction to reach the somato-splanchnopleuric angle, under cover of the growing myotome. It spreads out at its distal end and eventually separates into two portions: a smaller, splanchnic, or visceral; and a larger, somatic, or parietal portion. (1) The smaller, **splanchnic**, or **visceral portion** grows inwards, dorsal to the Wolffian ridge, to be connected with the sympathetic cord and the innervation of organs in the splanchnic area. This branch of the spinal nerve becomes the **white ramus communicans** of the sympathetic. It is not present in the case of all the spinal nerves (cervical, lower lumbar, and upper sacral). It will be referred to again in connexion with the sympathetic system. (2) The larger, **somatic**, or **parietal portion** becomes the main part of the anterior primary division of the nerve. It continues the original ventral course of the nerve, and, reaching the body wall, subdivides into two terminal branches—a lateral branch, which grows outwards and downwards and reaches the lateral aspect of the trunk, after piercing the myotome; and a ventral or anterior branch, which grows onwards in the body wall to reach the ventral axis. This arrangement is met with in the trunk between the limbs and in the neck.

III. **Formation of Limb-plexuses.**—The method of growth of the spinal nerves, just described, is modified in the regions where the limbs are developed. In relation to the limbs, which exist in the form of buds of cellular undifferentiated mesoblast before the spinal nerves have any connexion with them, the development of the nerve proceeds exactly in the way described up to the point of formation of somatic and splanchnic branches. The **somatic branches** then stream out into the limb bud, passing into it below the ends of the myotomes and spreading out into a bundle of fibres at the basal attachment of the limb. Later on, the nerves separate each into a pair of definite trunks, which are named **dorsal** and **ventral**, and which, dividing round a central core of mesoblast, proceed to the dorsal and ventral surfaces respectively of the limb bud. While this process is going on, a *secondary union* takes place between (parts of) adjacent dorsal and ventral trunks. Dorsal trunks unite with dorsal trunks, ventral trunks unite with ventral trunks, to form the nerves distributed ultimately to the surfaces and periphery of the limb. These **dorsal and ventral trunks** are homologous with the **lateral and ventral branches** of the somatic nerves in other regions.

Morphology of the Limb-plexuses.

The arrangement of the limb nerves is rendered complex and the significance of the plexuses is obscured by the changes through which, coincidently, the nerves on the one hand and the parts supplied by them on the other hand have passed in the course of development.

Nature of the Limbs.—As already described, the mammalian limbs arise as flattened buds from the extremities of the **Wolffian ridge**. Each bud possesses a *preaxial* and a *postaxial border*, and a *dorsal* and a *ventral surface*, continuous with the dorsal and ventral aspects of the trunk and homologous with its lateral and ventral surfaces. Each bud consists at first of a mass of undifferentiated, unsegmented mesoblast, covered by epithelium. Around the central core of mesoblast which produces the skeletal axis, the vessels and muscles of the limb are formed *in situ*, the muscles as double dorsal and ventral strata, beneath the corresponding surfaces of the bud.

Each limb bud is connected to the lateral and ventral aspects of the trunk, and is associated with a number of body segments, varying in the two extremities and in different animals.

Although the mesoblastic material of which the limb bud is composed exhibits in itself no segmental divisions at any period of its development, a clear indication of the segmental relations of the limbs is obtained from the arrangement of the limb nerves. Taking the nerves which supply the limbs as a guide, the segments engaged in the formation of the upper extremity are the last five cervical and first two thoracic. The lower extremity is related by its nerves to all the lumbar and the first three sacral segments. In each limb, the segments at the preaxial and postaxial borders are only partially concerned in limb formation.

It has been already shown that the somatic branches of the nerves enter the substance of the embryonic limb and divide in their course into dorsal and ventral trunks, which supply the dorsal and ventral surfaces of the limb bud. The higher nerves supply the preaxial border, the lower nerves supply the postaxial border, while the nerves most centrally situated extend furthest towards the periphery of the limb.

In order to understand properly the constitution of the limb-plexuses, it is necessary further to make a comparison of the surfaces and borders of the embryonic and adult limbs.

Upper Limb.—(*A*) **Borders.**—The **preaxial border** of the upper extremity extends from the middle of the clavicle, in the line of the cephalic vein, down the front of the shoulder, the outer side of the arm, forearm and hand, to the outer border of the thumb. The **postaxial border** extends from the middle of the axilla along the inner side of the arm (in the line of the basilic vein), the inner side of the forearm and hand, to the inner border of the little finger.

(*B*) **Surfaces.**—The areas of the limb between these lines, anteriorly and posteriorly, correspond to the ventral and dorsal surfaces of the embryonic limb bud. The **ventral surface** is represented by the front of the chest, arm, and forearm, and the palm of the hand. The **dorsal surface** is represented by the scapular and deltoid regions, the back of the arm, forearm, and hand.

Lower Limb.—(*A*) **Borders.**—The **preaxial border** of the lower limb extends from the middle of Poupart's ligament down the inner side of the thigh and leg in the line of the internal saphenous vein, to the inner side of the great toe. The **postaxial border**, beginning at the coccyx, extends along the fold of the nates and the outer side and back of the thigh and leg (in the line of the external saphenous vein) to the outer border of the foot and little toe.

(*B*) **Surfaces.**—The areas between these lines correspond to the primitive dorsal and ventral surfaces of the embryonic limb bud. The unequal amount of rotation in the parts of the lower limb obscures the relation of fœtal and adult surfaces, which are most easily made out in the infantile position of the limbs, with the thighs and knees flexed and the soles of the feet inverted. The **ventral surface** of the embryonic limb is represented by the inner side and back of the thigh, the back of the leg, and the sole of the foot. The **dorsal surface** is represented by the front of the thigh and buttock, the front of the leg, and the dorsum of the foot.

Composition of the Limb-plexuses.—In all mammals the same definite plan underlies the constitution of the limb-plexuses. The nerves concerned are the anterior primary divisions of certain segmental spinal nerves, which (with certain exceptions at the preaxial and postaxial borders) are destined wholly and solely for the innervation of the limb. Each of the anterior primary divisions engaged divides into a pair of **secondary trunks**, named **dorsal** or posterior, **ventral** or anterior. The dorsal and ventral trunks again subdivide into **tertiary trunks**, which combine with the corresponding subdivisions of neighbouring dorsal and ventral trunks to form the **nerves of distribution**. The combinations of *dorsal trunks* provide a series of nerves for the supply of that part of the limb which is derived from the *dorsal surface* of the embryonic limb bud; the combinations of *ventral trunks* give rise to nerves of distribution to the regions corresponding to its *ventral surface*. The relation of the nerves derived from the limb-plexuses to the areas of the limbs is given in the accompanying tables :—

I. Upper Limb.

Origin.		Nerves.	Distribution.	
Brachial Plexus	Dorsal trunks (*Posterior cord*)	Posterior scapular	Scapular region and shoulder	Dorsal surface
		Posterior thoracic		
		Suprascapular		
		Subscapular (3)		
		Circumflex		
		(Lesser internal cutaneous (?))	Arm, inner side	
		(Intercosto-humeral (?))		
		Musculo-spiral	Back of arm, forearm, and hand	
	Ventral trunks (*Outer and inner cords*)	Nerve to subclavius	Front of chest	Ventral surface
		Anterior thoracic (2)		
		Musculo-cutaneous	Front of arm and forearm	
		Lesser internal cutaneous	Inner side of arm	
		Internal cutaneous	Front of arm and forearm	
		Median	Front of forearm and hand	
		Ulnar		

II. Lower Limb.

Origin.		Nerves.	Distribution.	
Lumbo-sacral Plexus	Dorsal trunks	Ilio-hypogastric (iliac branch)	Buttock	Dorsal surface
		Superior gluteal		
		Inferior gluteal		
		Nerve to pyriformis		
		Small sciatic		
		External cutaneous	Buttock and thigh, outer side and front	
		Genito-crural (crural branch)	Front of thigh	
		Anterior crural	Front and inner side of thigh, leg, and foot	
		Peroneal	Front of leg and foot	
	Ventral trunks	Ilio-hypogastric (hypogastric branch)	Abdominal wall (ventral surface)	Ventral surface
		Ilio-inguinal	Abdominal wall, thigh, and perineum	
		Genito-crural (genital branch)	Groin	
		Obturator	Thigh (inner side) and knee (back)	
		Nerve to obturator internus and superior gemellus		
		Nerve to quadratus femoris and inferior gemellus	Buttock and back of thigh	
		Nerve to hamstrings		
		Small sciatic	Back of thigh and perineum	
		Tibial	Back of knee, leg, and sole of foot	

In the regions of the limbs no anterior cutaneous branches, derived from the limb nerves, supply the trunk. The whole of the nerve is carried into the limb and is absorbed in its innervation, and the dorsal and ventral trunks forming the limb-plexuses are to be looked upon as homologous with the lateral and anterior trunks of an intercostal nerve. Two series of anomalies in relation to the formation and distribution of the nerves to the limbs must, however, be considered, because it has been suggested (Goodsir) that the nerves of the limbs are serially homologous with not the whole, but with only the lateral branches of the anterior primary divisions of the intercostal nerves.

(1) **Nerves in connexion with the primitive borders of the Limbs.—At the preaxial border of the upper limb,** at its root, the fourth cervical nerve, which supplies the anterior and lateral surfaces of the neck, is also distributed through the supraclavicular nerves to the skin of both ventral and dorsal surfaces of the limb. The nerves and surfaces are here not merely homologous, but in actual continuity.

At the preaxial border of the lower limb, similarly, the first lumbar nerve, by means of the ilio-hypogastric and ilio-inguinal branches, supplies on the one hand the buttock, in series with the lateral branches of the lower thoracic nerves, and, on the other hand, the lower part of the abdominal wall and the adjacent inner side of the thigh, in series with the anterior terminal branches of the lower thoracic nerves.

At the postaxial border of the upper limb the first and second thoracic nerves are concerned in supplying trunk segments as well as parts of the limb. The first thoracic nerve, besides supplying the limb through the inner cord of the plexus, also innervates at least the muscles of the first intercostal space; the second thoracic nerve is concerned in the innervation of the limb, principally by means of its lateral branch only, which, as the intercosto-humeral nerve, supplies the skin along the postaxial border of the limb and on its *dorsal side.* **At the postaxial border of the lower limb,** in the same way, the third and fourth sacral nerves, partially implicated in the innervation of the limb (through the tibial, small sciatic, perforating cutaneous nerve, and perineal branch of the fourth sacral nerve), are also engaged in supplying the trunk (perineum) through the pudic nerve. These peculiarities of arrangement of the nerves at the borders of the limbs may be explained on the supposition that the segment corresponding to the nerve named is only partially concerned in limb formation, and is, at the same time, implicated to a greater or less extent in the formation of structures belonging to the trunk.

(2) **The origin and distribution of the nerves at the postaxial border of the limbs** present a special difficulty. In the composition respectively of the brachial and lumbo-sacral plexuses, the first thoracic and third sacral nerves do not as a rule divide into ventral and dorsal trunks, but contribute only to the formation of the ventral series of nerves. A solution of this difficulty may be found in the examination of the areas of distribution of the nerves derived from the first thoracic and third sacral nerves. In the case of the brachial plexus (the inner cord of which

receives normally the whole contribution of the first thoracic nerve) the lesser internal cutaneous, the inner branch of the internal cutaneous, and the dorsal branch of the ulnar nerve supply the dorsal aspect of the limb on its postaxial border. These nerves are in serial homology with the intercosto-humeral and lateral trunks of intercostal nerves. In the case of the lumbo-sacral plexus similarly, in which the third sacral nerve does not divide into ventral and dorsal trunks, the small sciatic and tibial nerves containing the contribution from the third sacral nerves innervate, by means of the gluteal and external femoral branches of the former and the tibial communicating branch of the latter, the dorsal surface of the limb along the postaxial border, in series with the perforating cutaneous nerve and the perineal branch of the fourth sacral.

These apparent anomalies appear to indicate that, instead of dividing into its proper dorsal and ventral trunks, the entire contribution of the spinal nerve concerned is in these instances carried undivided along the postaxial border of the limb in association with the ventral trunks, and that the dorsal subdivisions are thrown off successively as the plexus cords approach the periphery. Indeed, in the case of the small sciatic nerve, Eisler has shown that, when the peroneal and tibial nerves are separated at their origin, its gluteal and external femoral branches arise from and are connected with the dorsal, and the perineal and internal femoral branches with the ventral trunk.

The Distribution of the Spinal Nerves to the Muscles and Skin of the Limbs.

By dissection, experiment, and clinical observation, it is conclusively proved that as a rule each nerve of distribution in the limb, whether to muscle or skin, is made up of fibres derived from more than one spinal nerve; and, further, that in cutaneous distribution a considerable overlapping occurs in the course of the several peripheral nerves. Moreover, the arrangement of the distribution of the nerves to skin and to muscles is not identical. In the case of the skin of the limbs, by the covering of the limb being drawn on to it from adjacent parts in the process of growth, cutaneous nerves are engaged, which are derived from sources not represented in the muscular innervation of the limbs. Again, among the muscles, some have undergone fusion, others have become rudimentary, and others again have altered their position in the limb. Bearing these qualifications in mind, it is possible to formulate a definite plan for the innervation of the skin and muscles of the upper and lower limb. The accompanying tables give an analysis of the distribution of the spinal nerves to the skin and muscles of the upper and lower limb respectively:—

I. Upper Limb.

A. Cutaneous Nerves.

1. Dorsal (Posterior) Surface.

Regions.		Nerves.	Spinal Origins. *Preaxial Nerves.*	Spinal Origins. *Postaxial Nerves.*
Scapular	Upper part (*preaxial*)	Posterior primary divisions, cervical	C. 4. 5. 6.	
		Cervical plexus, acromial	C. 3. 4.	
	Lower part (*postaxial*)	Posterior primary divisions, thoracic	T. 1.-7.	
		Intercostal nerves, lateral branches	T. 2. 3. 4.	
Deltoid	Upper part (*preaxial*)	Cervical plexus, acromial	C. 3. 4.	
		Circumflex	C. 5. 6.	
	Lower part (*postaxial*)	Intercostal nerves, lateral branches		T. 2. 3.
Upper arm	Outer side (*preaxial*)	Circumflex	C. 5. 6.	
		Musculo-spiral, upper external branch	C. (5). 6.	
	Inner side (*postaxial*)	Musculo-spiral, internal branch	C. 8.	
		Lesser internal cutaneous		T. 1.
		Intercosto-humeral		T. 2.

1. Dorsal (Posterior) Surface—*continued.*

Regions.		Nerves.	Spinal Origins. *Preaxial Nerves.*	Spinal Origins. *Postaxial Nerves.*
Forearm	Outer side (*preaxial*)	Musculo-spiral, upper external branch	C. (5). 6.	
		Musculo-spiral, lower external branch	C. 6. 7. 8.	
		Musculo-cutaneous, posterior branch	C. 5. 6.	
		Radial	C. 6. 7.	
	Inner side (*postaxial*)	Internal cutaneous, internal branch		C. 8. T. 1.
		Ulnar, dorsal branch		C. 8.
Hand	Outer side (*preaxial*)	Radial	C. 6. 7.	
	Inner side (*postaxial*)	Ulnar		C. 8.

I. Upper Limb.

A. Cutaneous Nerves.

2. Ventral (Anterior) Surface.

Regions.		Nerves.	Spinal Origins. *Preaxial Nerves.*	Spinal Origins. *Postaxial Nerves.*
Chest	Upper part (*preaxial*)	Cervical plexus, supraclavicular branches	C. 3. 4.	
	Lower part (*postaxial*)	Intercostal nerves, anterior branches		T. 2.-7.
		Intercostal nerves, lateral branches		
Upper arm	Outer part (*preaxial*)	Circumflex	C. 5. 6.	
		Musculo-spiral, upper external branch	C. 5. 6.	
	Inner part (*postaxial*)	Internal cutaneous		C. 8. T. 1.
		Lesser internal cutaneous		T. 1.
		Intercosto-humeral		T. 2.
Forearm	Outer part (*preaxial*)	Musculo-cutaneous, anterior branch	C. 5. 6.	
	Inner part (*postaxial*)	Internal cutaneous, anterior branch		C. 8. T. 1.
Hand	Outer part (*preaxial*)	Musculo-cutaneous, ball of thumb	C. 5. 6.	
		Median, palmar branch	C. 6. 7.	
		„ digital branches	C. 6. 7. 8. T. 1.	
		„ thumb, outer side	C. 6. (7).	
		„ „ inner side	C. 6. 7.	
		„ index, outer side		
		„ „ inner side	C (6). 7. 8. (T. 1).	
		„ middle, outer side		
		„ „ inner side		C. 8. T. 1.
		„ ring, outer side		
	Inner part (*postaxial*)	Ulnar, palmar branch		T. 1.
		„ digital branches		T. 1.

I. Upper Limb.

B. Muscular Nerves.

1. Dorsal (Posterior) Surface.

Regions.	Muscles.	Nerves.	Spinal Origins. *Preaxial Nerves.*	Spinal Origins. *Postaxial Nerves.*
Shoulder — Upper part (*preaxial muscles*)	Trapezius	Cervical plexus	C. 3. 4.	
	Levator anguli scapulæ	Cervical plexus	C. 3. 4.	
		Posterior scapular	C. 5.	
	Rhomboidei	Posterior scapular	C. 5.	
	Serratus magnus	Posterior thoracic	C. 5. 6. 7.	
	Supraspinatus, Infraspinatus	Suprascapular	C. 5. 6.	
	Subscapularis	Short subscapular, Lower „	C. 5. 6.	
	Teres major	Lower subscapular	C. 5. 6.	
Shoulder — Lower part (*postaxial muscles*)	Teres minor, Deltoid	Circumflex	C. 5. 6.	
	Latissimus dorsi	Long subscapular		C. 6. 7. 8.
Upper arm	Triceps: Outer head	Musculo-spiral	C. (6). 7. 8.	
	Triceps: Middle head, Inner head	Musculo-spiral		C. 7. 8.
	Anconeus	Musculo-spiral		C. 7. 8.
Forearm	Brachio-radialis	Musculo-spiral	C. 5. 6.	
	Extensor carpi radialis longior	Musculo-spiral	C. (5). 6. 7. 8.	
	Extensor carpi radialis brevior	Posterior interosseous	C. (5). 6. 7. (8).	
	Supinator radii brevis	Posterior interosseous	C. (5). 6.	
	Extensor communis digitorum, „ minimi digiti, „ carpi ulnaris	Posterior interosseous	C. (5). 6. 7. 8.	
	Extensor ossis metacarpi pollicis, Extensor longus pollicis, „ brevis pollicis, „ indicis	Posterior interosseous	C. (5). 6. 7. 8.	

I. Upper Limb.

B. Muscular Nerves.

2. Ventral (Anterior) Surface.

Regions.	Muscles.	Nerves.	Spinal Origins. *Preaxial Nerves.*	Spinal Origins. *Postaxial Nerves.*
Pectoral Region — Upper part (*preaxial muscles*)	Sterno-mastoid	Cervical plexus	C. 2.	
	Omo-hyoid, Sterno-hyoid	Ansa hypoglossi	C. 1. 2. 3.	
	Subclavius	Brachial plexus	C. 5. 6.	
Pectoral Region — Lower part (*postaxial muscles*)	Pectoralis major: Clavicular part	Anterior thoracic nerves	C. 5. 6.	
	Pectoralis major: Sternal part	Anterior thoracic nerves	C. 5. 6. 7. 8. T. 1.	
	Pectoralis minor	Anterior thoracic nerves		C. 7. 8. T. 1.

2. **Ventral (Anterior) Surface**—*continued.*

Regions.		Muscles.	Nerves.	Spinal Origins. *Preaxial Nerves.*	Spinal Origins. *Postaxial Nerves.*
Upper arm	Outer part (*preaxial*)	Biceps	Musculo-cutaneous	C. 5. 6.	
		Brachialis anticus	Musculo-cutaneous	C. 5. 6.	
			Musculo-spiral	C. (5). 6.	
		Coraco-brachialis	Musculo-cutaneous	C. 7.	
	Inner part (*postaxial*)	Axillary arches	Internal anterior thoracic, or lesser internal cutaneous, or inter-costo-humeral		C. 8. T. 1. (2).
Forearm	Outer part (*preaxial*)	Pronator radii teres	Median	C. 6.	
		Flexor carpi radialis	Median	C. 6.	
		Palmaris longus	Median		
		Flexor sublimis digitorum	Median		
		Flexor profundus digitorum	Anterior interosseous : Ulnar		C. 7. 8. T. 1. C. 8. T. 1.
		Flexor carpi ulnaris	Ulnar		C. 8. T. 1.
	Inner part (*postaxial*)	Flexor longus pollicis	Anterior interosseous	C. 7. 8. T. 1.	
		Pronator quadratus	Anterior interosseous	C. 7. 8. T. 1.	
Hand	Outer part (*preaxial*)	Abductor pollicis	Median	C. 6. 7.	
		Opponens pollicis	Median	C. 6. 7.	
		Flexor brevis pollicis	Median	C. 6. 7.	
		Two outer lumbricales	Median	C. 6. 7.	
		Two inner lumbricales	Ulnar		C. 8. (T. 1).
		Interossei	Ulnar		C. 8. (T. 1).
		Adductores pollicis (transversus et obliquus)	Ulnar		C. 8. (T. 1).
	Inner part (*postaxial*)	Abductor minimi digiti	Ulnar		C. 8. (T. 1).
		Opponens minimi digiti	Ulnar		C. 8. (T. 1).
		Flexor brevis minimi digiti	Ulnar		C. 8. (T. 1).

II. Lower Limb.

A. Cutaneous Nerves.

1. Dorsal Surface.

(*Front and outer side of thigh, buttock, front of leg, dorsum of foot.*)

Regions.		Nerves.	Spinal Origins. *Preaxial Nerves.*	Spinal Origins. *Postaxial Nerves.*
Front of thigh and front part of buttock (*preaxial nerves*)	Thigh	Genito-crural, crural branch	L. 1. 2.	
		Anterior crural, internal branch	L. 2. 3.	
		Anterior crural, middle branch	L. 2. 3.	
		External cutaneous	L. 2. 3.	
	Buttock	Twelfth thoracic, iliac branch	T. 12.	
		Ilio-hypogastric, iliac branch	L. 1.	
		Posterior primary divisions, lumbar	L. 1. 2. 3.	
		Posterior primary divisions, sacral		S. 1.-5.
Outer side of thigh and buttock, back and lower part (*postaxial nerves*)		Posterior primary divisions, coccygeal		Co.
		Small sciatic : gluteal, and femoral branches		S. 1. 2. 3.
Leg	Inner side (*preaxial*)	Internal saphenous	L. 3. 4.	
		Patellar branch	L. 3. 4.	
	Outer side (*postaxial*)	Musculo-cutaneous	L. 4. 5. S. 1.	
		Peroneal, sural branches	L. (4). 5. S. 1.	
Dorsum of foot	Inner side (*preaxial*)	Internal saphenous	L. 3. 4.	
		Anterior tibial	L. 4. 5. (S. 1).	
	Outer side (*postaxial*)	Musculo-cutaneous	L. 4. 5. S. 1.	
		External saphenous		S. 1. (2).

II. Lower Limb.

A. Cutaneous Nerves.

2. Ventral Surface.

(*Inner side and back of thigh, back of leg, and sole of foot.*)

Regions.		Nerves.	Spinal Origins. *Preaxial Nerves.*	*Postaxial Nerves.*
Inner side and back of thigh	Inner side of thigh (*preaxial*)	Ilio-inguinal	L. 1.	
		Obturator	L. 2. 3. (4).	
	Back of thigh (*postaxial*)	Small sciatic, femoral branches	S. 1. 2. 3.	
Back of leg		Peroneal, sural branches	L. (4). 5. S. 1.	
		Peroneal, communicans fibularis		
		Small sciatic	S. 1. 2. 3.	
		External saphenous	S. 1. (2).	
Sole of foot	Inner side (*preaxial*)	Internal saphenous	L. 3. 4.	
		Posterior tibial, calcanean		S. 1. 2.
		Internal plantar	L. 4. 5. S. 1.	
		Great toe, inner side	L. 4. 5.	
		„ „ outer side	L. 4. 5. S. 1.	
		Second toe, inner side		
		„ „ outer side		
		Third toe, inner side	L. 5. S. 1.	
		„ „ outer side		
		Fourth toe, inner side		
	Outer side (*postaxial*)	External plantar	S. 1. 2.	
		Fourth toe, outer side		
		Fifth toe, inner side		
		„ „ outer side		
		External saphenous	S 1. (2).	

II. Lower Limb.

B. Muscular Nerves.

1. Dorsal Surface.

(*Front and outer side of thigh, buttock, front and outer side of leg, dorsum of foot.*)

Regions.	Muscles.	Nerves.	Spinal Origins. *Preaxial Nerves.*	*Postaxial Nerves.*
Front of thigh (*preaxial*)	Pectineus	Anterior crural	L. 2. 3.	
	Sartorius			
	Iliacus		L. 2. 3. 4.	
	Psoas			
	Quadriceps extensor		L. 3. 4.	
	Vastus internus			
	Rectus femoris			
	Crureus			
	Vastus externus			
Buttock and outer side of thigh (*postaxial*)	Tensor fasciæ femoris	Superior gluteal	L. 4. 5. S. 1	
	Gluteus minimus			
	„ medius			
	„ maximus	Inferior gluteal	L. 5. S. 1. 2.	
	Biceps, short head	Peroneal		
	Pyriformis	Sacral plexus		S. 1. 2.

1. **Dorsal Surface**—*continued.*

Regions.		Muscles.	Nerves.	Spinal Origins. *Preaxial Nerves.*
Front of leg	Inner side (*preaxial*)	Tibialis anticus	Anterior tibial	L. 4. 5. S. 1.
		Extensor proprius hallucis		
		Extensor longus digitorum		
		Peroneus tertius		
	Outer side (*postaxial*)	Peroneus longus	Musculo-cutaneous	
		Peroneus brevis		
Dorsum of foot		Extensor brevis digitorum	Anterior tibial	

II. Lower Limb.

B. Muscular Nerves.

2. **Ventral Surface.**

(*Inner side and back of thigh, back of leg, and sole of foot.*)

Regions.		Muscles.	Nerves.	Spinal Origins. *Preaxial Nerves.*	Spinal Origins. *Postaxial Nerves.*
Thigh and buttock	Thigh, inner side (*preaxial*)	Adductor longus	Obturator	L. 2. 3.	
		Gracilis		L. 2. 3. 4.	
		Adductor brevis		L. 3. 4.	
		Obturator externus			
		Adductor magnus			
	Thigh, outer side (*postaxial*)	Adductor magnus	Nerve to hamstrings	L. 4. 5. S. 1.	
		Semi-membranosus		L. 5. S. 1. 2.	
		Semi-tendinosus			S. 1. 2. 3.
		Biceps, long head			
	Buttock	Quadratus femoris and superior gemellus	Sacral plexus	L. 4. 5. S. 1.	
		Inferior gemellus and obturator internus			S. 1. 2. 3.
Back of leg		Plantaris	Tibial	L. 4. 5. S. 1.	
		Popliteus			
		Flexor longus digitorum	Posterior tibial	L. 5. S. 1.	
		Tibialis posticus			
		Flexor longus hallucis			L. 5. S. 1. 2.
		Soleus			
		Soleus	Tibial		S. 1. 2.
		Gastrocnemius (each head)			
Sole of foot	Inner side (*preaxial*)	Abductor hallucis	Internal plantar	L. 4. 5. S. 1.	
		Flexor brevis digitorum			
		Flexor brevis hallucis			
		First lumbricalis			
	Outer side (*postaxial*)	Second, third, and fourth lumbricales	External plantar		S. 1. 2.
		Flexor accessorius			
		Adductores hallucis			
		Interossei			
		Flexor brevis minimi digiti			
		Abductor minimi digiti			

A. **Innervation of the Muscles of the Limbs.**—The following laws appear to be applicable to the upper and lower limbs alike :—

1. *No limb-muscle receives its nerve-supply from posterior primary divisions.*

2. *The dorsal and ventral strata of muscles are always supplied by the corresponding dorsal and ventral branches of the nerves concerned. The ventral muscular stratum is more extensive than the dorsal; the ventral nerves are the more numerous, and the additional nerves are postaxially placed.* The spinal nerves supplying muscles of the upper limb are C. 5, 6, 7, 8 (dorsal), and C. 5, 6, 7, 8, T. 1 (ventral); the nerves for the muscles of the lower limb are L. 2, 3, 4, 5, S. 1, 2 (dorsal), and L. 2, 3, 4, 5, S. 1, 2, 3 (ventral).

3. *The dorsal and ventral trunks of the nerves are distributed in the limb in a continuous, segmental manner*; so that, "of two muscles, that nearer the head end of the body tends to be supplied by the higher nerve, and that nearer the tail end by the lower nerve" (Herringham).

4. *The nerves placed most centrally in the plexus extend furthest into the limb, and the more preaxial nerves terminate sooner in the limb than the more postaxial nerves.*

Upper Limb.

Dorsal Surface.		Ventral Surface.	
Muscles of shoulder .	C. 3, 4, 5, 6, 7, 8.	Muscles of chest .	C. 5, 6, 7, 8, T. 1.
„ arm . .	C. 6, 7, 8.	„ arm .	C. 5, 6, 7.
„ forearm .	C. 6, 7.	„ forearm .	C. 6, 7, 8, T. 1.
		„ hand .	C. 6, 7, 8 (T. 1).

Lower Limb.

Muscles of thigh and buttock . . .	L. 2, 3, 4, 5, S. 1, 2.	Muscles of thigh .	L. 2, 3, 4, 5, S. 1, 2, 3.
Muscles of leg and foot	L. 4, 5, S. 1.	„ leg .	L. 4, 5, S. 1, 2.
		„ foot .	L. 5, S. 1, 2.

The only exception to this rule is on the ventral (anterior) surface of the upper arm, where a suppression of the muscle elements leads to an absence of the regular series of segmental nerves (C. 8, T. 1) on its postaxial border. These nerves reappear in the forearm, and the occasional

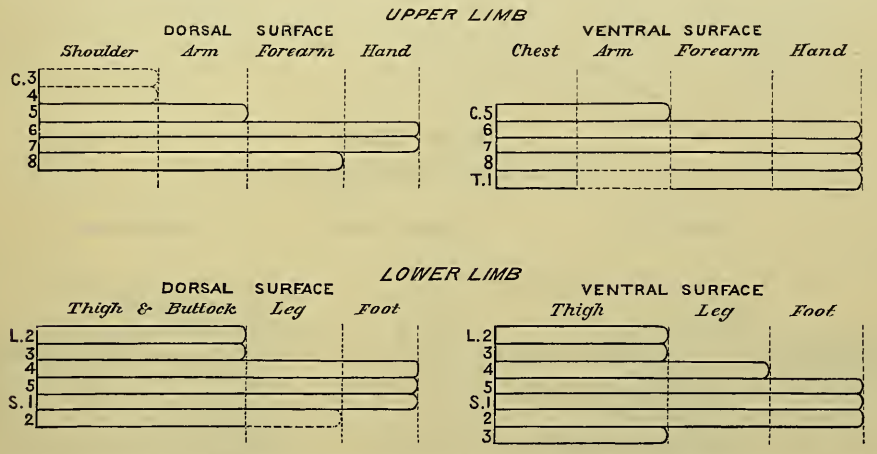


FIG. 516.—SCHEME of the segmental distribution of the muscular nerves of the upper and lower limbs.

"axillary arches" may be regarded as the muscular elements usually suppressed, and, when present, supplied by these nerves.

Muscles with a Double Nerve-supply.—The existence of more than one nerve to a muscle indicates usually that the muscle is composite and is the representative of originally separate elements, belonging to more than one segment or to both surfaces of the limb. In the case of the pectoralis major, subscapularis and flexor profundus digitorum, adductor magnus, and soleus, parts of the same (ventral or dorsal) stratum have fused, to form muscles innervated from the corresponding ventral or dorsal nerves. The other muscles having a double nerve-supply—brachialis anticus, biceps flexor cruris, and (sometimes) pectineus—are examples of fusion at the preaxial or postaxial border of muscular elements derived from the dorsal and ventral surfaces of the limb, which are correspondingly innervated by branches from both dorsal and ventral series: *e.g.* the brachialis anticus is innervated by the musculo-cutaneous and musculo-spiral nerves; the biceps flexor cruris, by the peroneal (short head) and tibial (long head) nerves; and the pectineus, by the anterior crural and (sometimes) obturator nerves.

B. **Innervation of the Skin of the Limbs.**—While the scheme of cutaneous innervation of the limbs is fundamentally segmental, yet the arrangement is confused and complicated by various causes. The growth of the limb from the trunk has caused the skin to be drawn out over it like a stretched sheet of india-rubber (Herringham), and at the same time the extent of the dorsal area of the limb is increased at the expense of the ventral area. The central nerves of the plexus remain buried deeply in the substance of the limb, only coming to the surface towards the periphery. The proximal parts of both surfaces of the limb thus become innervated by

cutaneous nerves otherwise not necessarily concerned in the innervation of the limbs. Herringham has shown that—(A) *Of two spots on the skin, that nearer the preaxial border tends to be supplied by the higher nerve.* (B) *Of two spots in the preaxial area, the lower tends to be supplied by the lower nerve; and of two spots in the postaxial area, the lower tends to be supplied by the higher nerve.* In other words, from the root of the limb down the preaxial border to its distal extremity, and up the postaxial border to the root of the limb again, there is a definite numerical sequence of spinal nerves supplying skin areas through nerves of the limb-plexuses. A similar numerical sequence in the arrangement of the nerves is also found extending over the dorsal and ventral surfaces of the limbs from preaxial to postaxial border, except in certain situations.

On the dorsal and ventral surfaces of both upper and lower limbs there is a hiatus, for a certain distance, in the numerical sequence of the spinal nerves in their cutaneous distribution, explicable on the ground that the central nerves of the plexus, which fail to reach the surface in these situations, are replaced by cutaneous branches from neighbouring nerves. This hiatus has been named the *axial area or line.*

In the upper limb, *the dorsal axial area or line* extends from the middle line of the back, opposite the vertebra prominens, to the insertion of the deltoid.

The ventral axial area or line extends anteriorly from the middle line of the trunk, at the manubrio-sternal joint, across the chest, down the front of the arm and forearm to the wrist.

In the lower limb, *the dorsal axial area or line* may be traced from the middle line of the back over the posterior superior iliac spine, across the buttock and thigh, to the head of the fibula.

A ventral axial area or line can also be traced from the root of the penis along the inner side of the thigh and knee, and down the back of the leg to the heel.

These areas or lines represent the meeting-place and overlapping of nerves, which are not in numerical sequence; and it is only at the peripheral parts of the limbs, on the dorsal and ventral surfaces, that the nerves appear in numerical sequence from the preaxial to the postaxial border. In the case of the upper limb the hiatus is caused, in both surfaces of the limb, by the absence of cutaneous branches of the seventh cervical nerve; in the case of the lower limb the hiatus is due to the absence of branches from the fifth lumbar nerve on both surfaces of the limb, and the absence of branches from the fourth lumbar nerve, in addition, on the dorsal surface.

Understanding the significance of these dorsal and ventral axial areas or lines, and at the same time bearing in mind the overlapping which occurs in the cutaneous distribution of each spinal nerve, the areas of skin supplied through the limb-plexuses can be mapped out with considerable precision, as indicated in the following tables :—

A. Upper Limb.

Cutaneous Distribution.

Nerves.		Spinal Origin.	Distribution.
Preaxial border from neck to hand ↓	Supraclavicular nerves	C. 3. 4.	Chest, shoulder, deltoid, and scapular regions.
	Circumflex	C. 5. 6.	Deltoid region, outer side of arm.
	Musculo-spiral (upper external)	C. (5). 6.	Outer side and back of arm and forearm.
	Musculo-spiral (lower external)	C. 6. 7. 8.	Outer side and back of elbow and forearm.
	Musculo-cutaneous	C. 5. 6.	Outer side of forearm, in front and behind.
Hand — Dorsum	Radial	C. 6. 7.	Outer side of dorsum of hand.
	Ulnar	C. 8.	Inner side of dorsum of hand.
Hand — Palm	Musculo-cutaneous	C. 5. 6.	Ball of thumb.
	Median	C. 6. 7.	Outer side of palm of hand.
	Ulnar	T. 1.	Inner side of palm of hand.
Digits	Median	C. 6. 7. 8. T. 1.	Thumb C. 6. 7.; First finger, C. 6. 7. 8.; Second „ C. 7. 8. T. 1.
	Ulnar	C. 8. T. 1.	Third „ C. 8. T. 1.; Fourth „ Fifth „ T. 1.
Postaxial border from hand to chest ↑	Internal cutaneous	C. 8. T. 1.	Inner side of forearm, in front and behind.
	Musculo-spiral (internal)	C. 8.	Inner side of arm.
	Lesser internal cutaneous	T. 1.	
	Intercosto-humeral	T. 2.	
	Intercosto-humeral	T. 2.	Axillary folds.
	Third intercostal	T. 3.	
	Fourth „	T. 4.	

B. Lower Limb.

Cutaneous Distribution.

Nerves.		Spinal Origin.	Distribution.
Preaxial border from trunk to foot ↓	Iliac branch of twelfth thoracic	T. 12.	Outer side of buttock.
	Iliac branch of ilio-hypogastric	L. 1.	Outer side of buttock.
	Ilio-inguinal	L. 1.	Groin and over Scarpa's triangle.
	Genito-crural	L. 1. 2.	Front of thigh, upper third.
	External cutaneous	L. 2. 3.	Front and outer side of thigh.
	Anterior crural (middle and internal)	L. 2. 3.	Front and inner side of thigh, lower two-thirds.
	Obturator	L. 2. 3. (4).	Inner side of thigh, middle third.
	Anterior crural (internal saphenous)	L. 3. 4.	Knee and leg, inner side and front.
Foot — Dorsum	Internal saphenous	L. 3. 4.	Inner side of foot.
	Anterior tibial	L. 4. 5. S. (1).	Interval between first and second toes.
	Musculo-cutaneous	L. 4. 5. S. 1.	Dorsum of foot and toes.
	External saphenous	S. 1. (2).	Outer side of foot.
Foot — Sole	Internal plantar	L. 4. 5. S. 1.	Inner part of sole.
	External plantar	S. 1. 2.	Outer part of sole.
	Posterior tibial (calcanean)	S. 1. 2.	Heel and back part of sole.
Digits	Internal and external plantar	L. 4. 5. S. 1. S. 1. 2.	Great toe, L. 4. 5. S. 1. Second toe, L. 4. 5. S. 1. Third „ L. 5. S. 1. Fourth „ L. 5. S. 1. 2. Fifth „ S. 1. 2.
Postaxial border from foot to coccyx ↑	External saphenous	S. 1. (2).	Outer side of foot and leg, lower third.
	Small sciatic	S. 1. 2. 3.	Back of leg, thigh, and buttock.
	Perforating cutaneous.	S. 2. 3.	Buttock (fold of nates, inner half).
	Sacro-coccygeal	S. 4. 5. Co. 1.	Anal fold.

Variations in the Position of the Limb-plexuses.

Two different kinds of variations occur in relation to the limb-nerves.

(1) **Individual variations,** in both the extent of origin and in the area of distribution of a given nerve, are not uncommon; these variations are usually concomitant with compensatory variations in adjacent nerves, and are due to the fibres of a given spinal nerve taking an abnormal course in the trunk of another nerve of distribution and effecting a communication with the proper nerve peripherally. In this way the variations in the origin and distribution of the intercosto-humeral nerve may be explained; and, similarly, the ulnar nerve may have some of its fibres carried as far as the forearm incorporated with the median and transferred to it by a communication between the two nerves in that region.

(2) **Variations in the limb-plexus,** in relation to the vertebral column, are the chief cause of variations in the constitution of the limb-nerves. These variations affect more or less the whole series of nerves in the plexus.

The **brachial plexus** is subject only to very slight variation in position and arrangement. It may be reinforced at the upper end by a slender trunk from the fourth cervical nerve, and, more frequently, by an intra-thoracic communication between the second and first thoracic nerves. The presence of one or other of these nerves is an indication of a slight tendency towards a cephalic or caudal shifting of the whole plexus in relation to the spinal cord. It is, however, never sufficient to cause the exclusion to any extent of the nerves normally implicated. The presence of a cervical rib may coincide with little or no change in the relation of the nerves. Indeed, the inclusion of the second thoracic nerve in the plexus may be, as already stated, merely an individual variation, a change in the path to the limb of the intercosto-humeral nerve. Concomitant variations occur among groups of nerves, however, which indicate a certain tendency to variation in the position of the whole plexus. At one end, the suprascapular and musculo-cutaneous nerves may arise from the fourth and fifth, fifth alone, or fifth and sixth cervical nerves. At the other end of the plexus, the musculo-spiral may or may not receive a root from the first thoracic nerve, and this addition is rather more likely to occur when the second thoracic nerve is implicated in the plexus.

The **lumbo-sacral plexus** shows a very considerable variability in position and constitution. Eisler records concomitant variations in the plexus in 18 per cent of the cases examined by him.

The variations occur within wide limits. The plexus may begin at the eleventh or twelfth thoracic or first lumbar nerve. The last nerve in the great sciatic cord may be the second, third, or fourth sacral nerve. The position of the n. furcalis is a guide to the arrangement of the plexus. It may be formed by the third, third and fourth, fourth, fourth and fifth, or fifth lumbar nerves. The resulting variations are illustrated by the following extreme cases:—

	(1) *Prefixed Variety.*	(2) *Postfixed Variety.*
Nervus furcalis	L. 3 and 4 (double).	L. 5.
Obturator	L. 1, 2, 3.	L. 2, 3, 4, 5.
Anterior crural	T. 12, L. 1, 2, 3, 4.	L. 2, 3, 4, 5.
Tibial	L. 3, 4, 5, S. 1, 2.	L. 5, S. 1, 2, 3, 4.
Peroneal	L. 3, 4, 5, S. 1.	L. 5, S. 1, 2, 3.

Those variations in the constitution of the lumbo-sacral plexus are most numerous which are due to the inclusion of nerves more caudally placed. Thus, out of twenty-two variations in the position of the *n. furcalis*, in nineteen Eisler found it formed by the fifth lumbar nerve; in two cases only, by the third lumbar nerve. There is further evidence that variations in the position of the plexus are accompanied by variations in the vertebral column itself. Out of the twenty-two abnormal plexuses examined by Eisler, sixteen were coincident with abnormal arrangement of the associated vertebræ.

Significance of the Limb-plexuses.

From the above considerations, it is obvious that something more than convenience of transit for the spinal nerves to skin and muscles is secured by the formation of the limb-plexuses. It has been shown that by their combinations in the plexuses, every spot or area of skin in the limbs is innervated by more than one spinal nerve; and generally, also, each limb-muscle is supplied by more than one spinal nerve. Each cutaneous area and each limb-muscle is thus brought into relationship with a wider area of the spinal cord than would occur if the plexuses were non-existent. A simultaneous record of sensation is thus transmitted from any given point on the surface of the limb through more than one dorsal root; and a more ready co-ordination of muscular movement is brought about by the transmission of motor impulses from the ventral root of a given spinal nerve to more than one muscle at the same time. In a word, a plexus exists to supply the whole limb and the limb as a whole, as an organ which has its different active parts connected with the central nervous system by means of the limb-plexus.

THE CRANIAL NERVES.

The series of cranial nerves is arranged in twelve pairs, which present striking differences in origin, in distribution, and in functions.

Number.	Name.	Function.	Superficial Attachment to Brain.
I.	**Olfactory**	Smell	Olfactory bulb.
II.	**Optic**	Sight	Optic thalamus.
III.	**Oculo-motor**	Motor to the muscles of eyeball and orbit	Crus cerebri.
IV.	**Trochlear**	Motor to superior oblique muscle of eyeball	Superior medullary velum.
V.	**Trigeminal**	Sensory to face, tongue, and teeth; motor to muscles of mastication	Pons Varolii.
VI.	**Abducent**	Motor to external rectus muscle of eyeball	Junction of pons and medulla.
VII.	**Facial**	Motor to muscles of scalp and face, sensory to tongue	Posterior border of pons Varolii.
VIII.	**Auditory**	Hearing and equilibrium	Posterior border of pons Varolii
IX.	**Glosso-pharyngeal**	Sensory to tongue and pharynx	Medulla oblongata.
X.	**Pneumogastric**	Sensory to pharynx, œsophagus and stomach, and respiratory organs	Medulla oblongata.
XI.	**Spinal accessory**	(*a*) **Accessory to vagus.**—Motor to muscles of palate, pharynx, œsophagus, stomach and intestines, and respiratory organs; inhibitory for heart	Medulla oblongata.
		(*b*) **Spinal part:** motor to trapezius and sterno-mastoid muscles	Spinal cord.
XII.	**Hypoglossal**	Motor to muscles of the tongue	Medulla oblongata.

The deep cerebral connexions of the cranial nerves are dealt with in the section which treats of the Brain (pp. 514 and 540). Certain general points in connexion with these nerves are also touched upon in the chapter introductory to the Nervous System (p. 443).

The First or Olfactory Nerve.

The olfactory nerve (n. olfactorius) consists of several parts: (1) a series of fine **nerves**, which arise from (2) the **olfactory bulb**. This again is connected by (3)

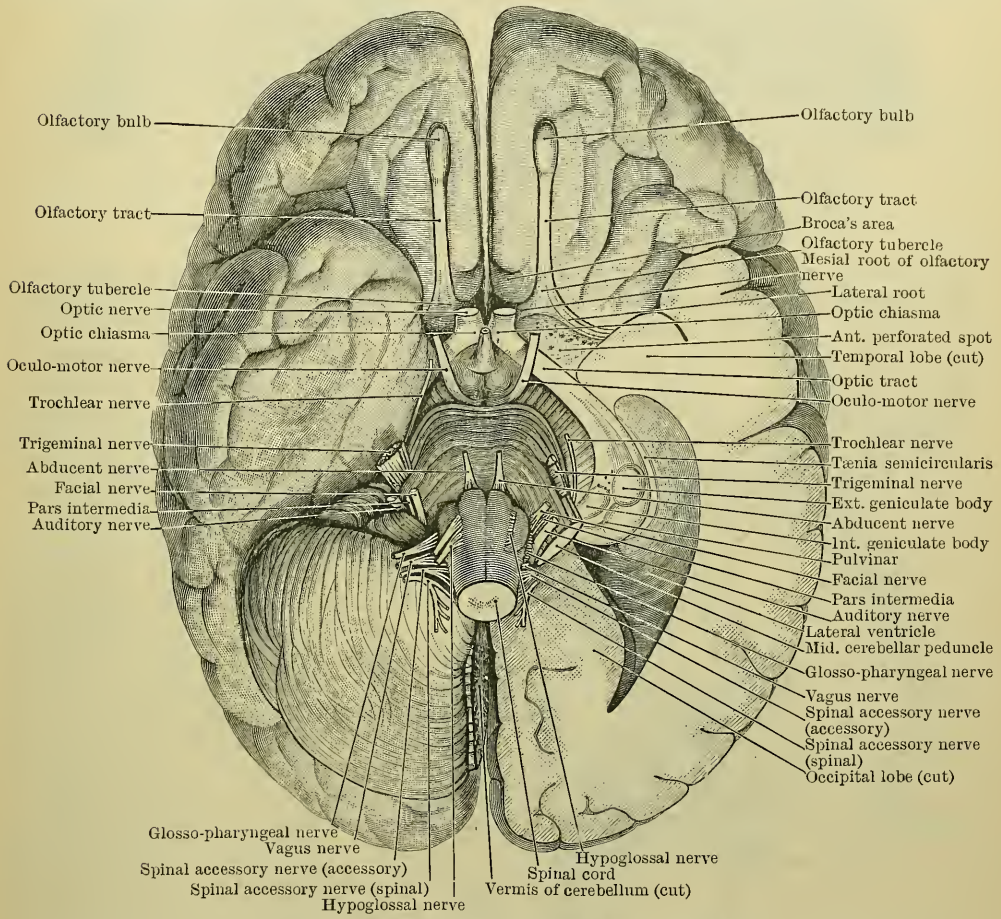


Fig. 517.—View of the Under Surface of the Brain, with the lower portion of the temporal and occipital lobes, and the cerebellum on the left side removed, to show the origins of the cranial nerves.

the **olfactory tract** with the brain, to which it is attached by (4) two **roots** (Fig. 517).

The anatomy of the roots, tract, and bulb of the olfactory nerve are described elsewhere (pp. 569 and 587).

The **olfactory nerves**, about twenty in number, arise from the under surface of the olfactory bulb. The fibres are non-medullated. Piercing the cribriform plate of the ethmoid bone, enveloped in sheaths of dura mater, they are distributed in the nasal cavity as the nerves of smell. The fibres form fine plexuses over a limited area on the upper portion of the nasal septum, and to even a less extent over the outer wall of the nose.

The Second or Optic Nerve.

The optic nerve (n. opticus) arises from the brain by means of the **optic tract** (Fig. 551). This takes origin from the external and internal geniculate bodies,

situated on the under surface of the optic thalamus at its posterior end, and also from the brachium of the upper of the two corpora quadrigemina (*vide* pp. 532 and 551). The optic tract reaches the base of the brain after sweeping round

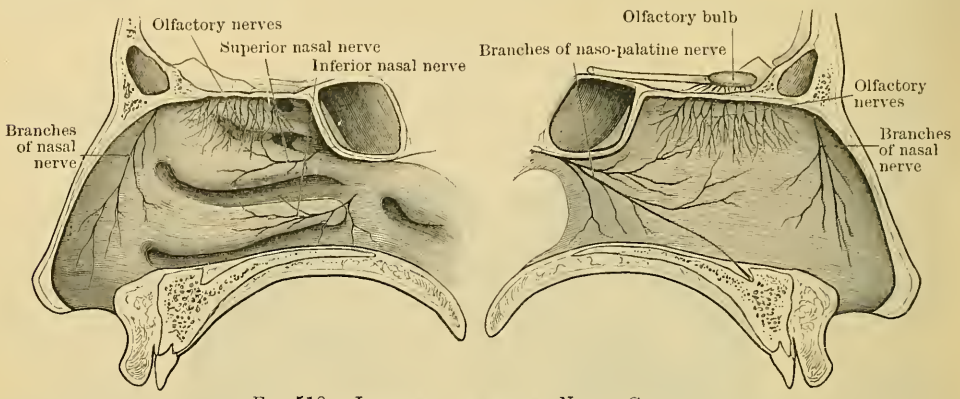


FIG. 518.—INNERVATION OF THE NASAL CAVITY.

between the crus cerebri and the hippocampal convolution of the temporal lobe. The two optic tracts converge in front of the inter-peduncular space, internal to the anterior perforated spot and the termination of the internal carotid artery, and unite to form the **optic chiasma** or **commissure.** This adheres to the under surface of the floor of the third ventricle in front of the tuber cinereum, and gives rise at each end to the **optic nerve.** The optic nerve, directed outwards and forward, pierces the dura mater, and passes from the cranial cavity into the orbit through the optic foramen in company with the ophthalmic artery. In the orbit the nerve is imbedded in the fat behind the eyeball, and is surrounded by the ocular muscles. It is connected with the globe of the eye at a point one-eighth of an inch on the inner side of the axis of the eyeball. After piercing the fibrous and vascular coats, the nerve spreads out at the **optic disc** to form the innermost layer of the **retina.** In the orbit the nerve is crossed by the ophthalmic artery and the nasal nerve, and nearer to its termination it is surrounded by the ciliary vessels and nerves, and by the capsule of Tenon. It is pierced obliquely on its under surface by the central artery of the retina.

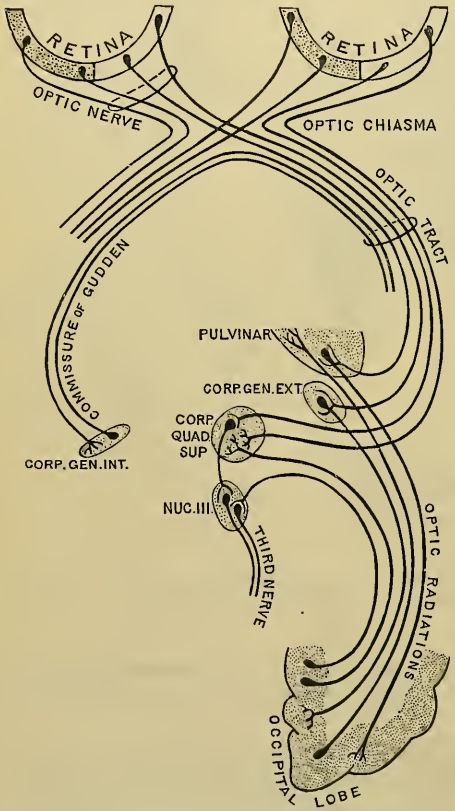


FIG. 519.—DIAGRAM OF THE CENTRAL CONNEXIONS OF THE OPTIC NERVE AND OPTIC TRACT.

Decussation in the Optic Commissure.—In the optic commissure the fibres of the two optic tracts separate, the inner half of each tract decussating to form the mesial half of the opposite optic nerve. The other, outer half of each tract, continues its course to form the outer half of the optic nerve on the same side. At the back of the commissure another bundle of fibres is found passing from tract to tract behind the decussating fibres, and known as **Gudden's commissure** (see p. 552).

THE THIRD OR OCULO-MOTOR NERVE.

The oculo-motor nerve (n. oculo-motorius) arises from the brain, in the region of the posterior perforated spot, by several radicles emerging from the **oculo-motor**

sulcus, on the inner side of the crus cerebri, just in front of the pons Varolii (Fig. 517). Passing forwards between the posterior cerebral and superior cerebellar arteries, the nerve pierces the dura mater on the outer side of the posterior clinoid process, in a small triangular space between the free and attached borders of the tentorium cerebelli. Beneath the dura mater the nerve courses through the outer wall of the cavernous sinus, and enters the orbit through the sphenoidal fissure

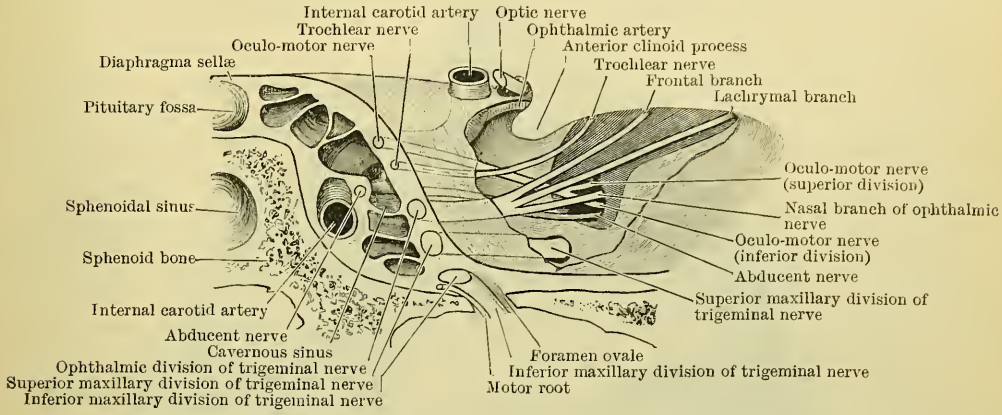


FIG. 520.—RELATIONS OF STRUCTURES IN THE CAVERNOUS SINUS AND SPHENOIDAL FISSURE.

and between the two heads of the external rectus muscle. As it enters the orbit it divides into upper and lower branches, separated by the nasal nerve.

Branches.—The **superior branch** of the nerve supplies two muscles of the orbit —the superior rectus and the levator palpebræ superioris.

The **inferior branch** passes forwards, and after giving branches to the internal and inferior recti, ends in the inferior oblique muscle. The short root of the ciliary ganglion arises from the terminal branch which goes to the last-named muscle.

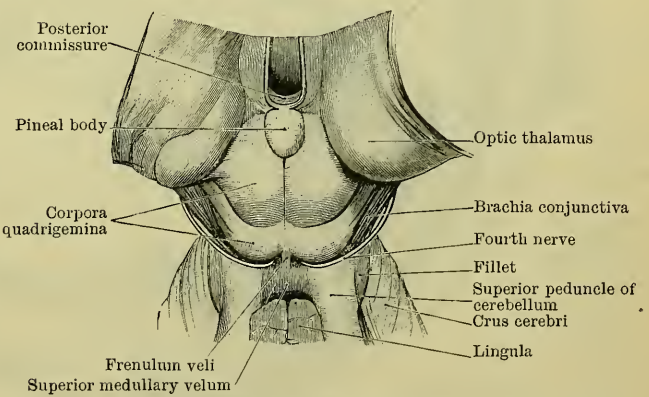


FIG. 521.—DORSAL SURFACE OF THE MID-BRAIN, to show the origin of the trochlear (fourth) nerve.

Communications.—1. In the cavernous sinus the third nerve communicates with the cavernous plexus on the internal carotid artery. 2. In the cavernous sinus it also receives a slender communication from the ophthalmic division of the fifth nerve. 3. The **short root of the ciliary ganglion** passes upwards from the branch of the nerve which supplies the inferior oblique muscle.

THE FOURTH OR TROCHLEAR NERVE.

The trochlear nerve (n. trochlearis or patheticus) emerges from the dorsal surface of the mid-brain. It springs at the side of the *frenulum* from the anterior end of the superior medullary velum, just behind the corpora quadrigemina (for deep origin, see p. 540). It is extremely slender, and of considerable length. Passing round the crus cerebri, the nerve appears in the base of the brain behind the optic tract, in the interval between the crus cerebri internally and the temporal lobe of the cerebrum externally. Continued forwards to the base of the skull, it pierces the free border of the tentorium cerebelli, on the outer side

of the third nerve, and proceeds forwards in the outer wall of the cavernous sinus, to the sphenoidal fissure lying between the third and ophthalmic nerves. It enters the orbit above the muscles of the eyeball, and terminates in the orbital (superior) surface of the superior oblique muscle.

Communications.—In the cavernous sinus the nerve receives (1) a communicating

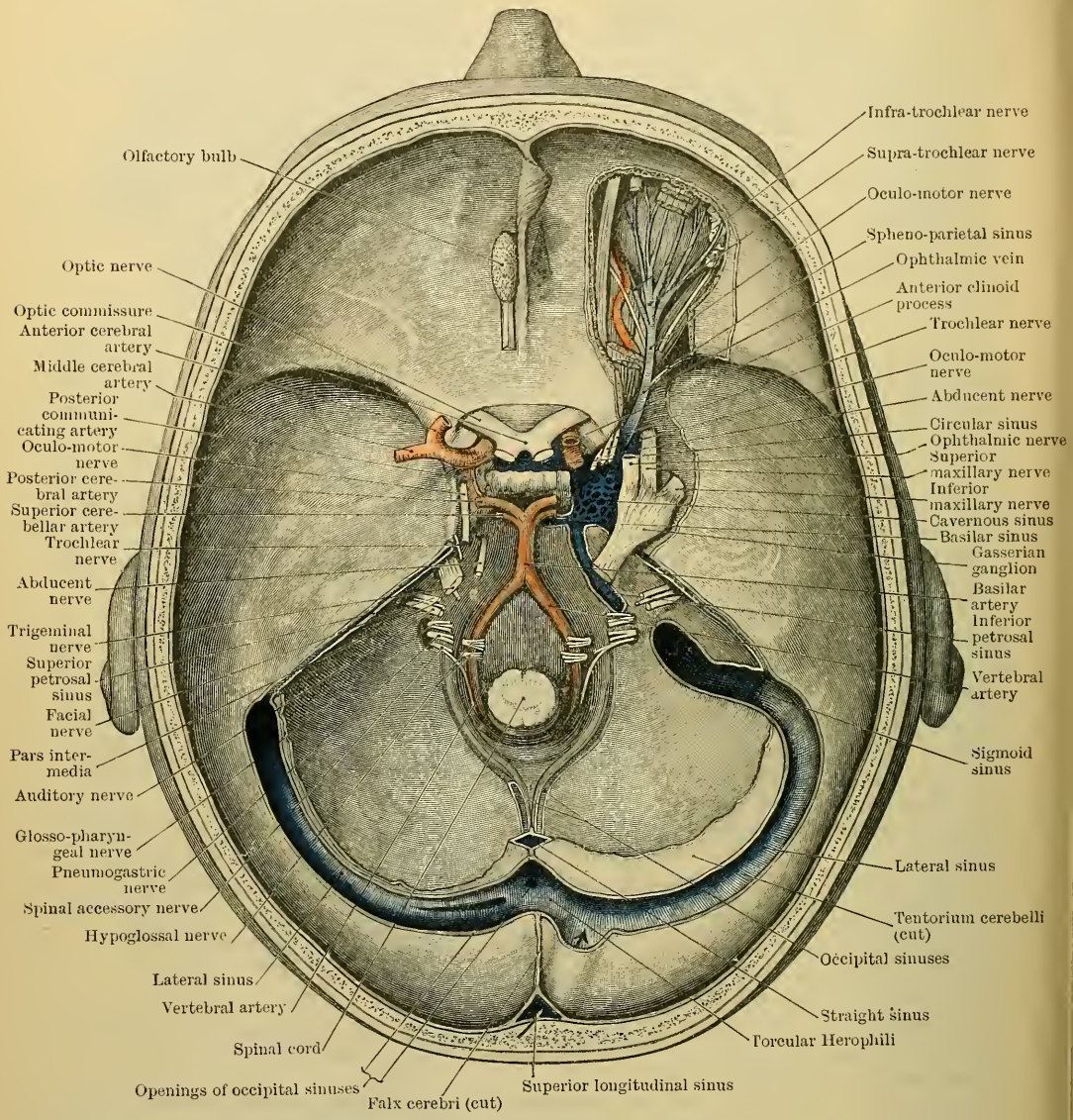


FIG. 522.—THE BASE OF THE SKULL, to show the dura mater, sinuses, arteries, and nerves.

branch from the cavernous or carotid plexus on the internal carotid artery, and (2) a slender filament from the ophthalmic division of the fifth nerve.

THE FIFTH, TRIGEMINAL OR TRIFACIAL NERVE.

The trigeminal nerve (n. trigeminus) arises from the surface of the pons Varolii in its outer part by two roots, a large **sensory root** (portio major) and a small **motor root** (portio minor) (Fig. 517, p. 675). The two roots proceed forwards in the posterior fossa of the base of the skull, and piercing the dura mater beneath the attachment of the tentorium cerebelli to the superior border of the petrous portion of the

temporal bone, enter a cavity in the dura mater (cavum Meckelii) over the apex of the petrous bone. The large sensory root gradually conceals the small motor root in its course forwards, and expands beneath the dura mater into a large flattened ganglion,—the **Gasserian ganglion** (ganglion semilunare). This ganglion occupies an impression on the apex of the petrous portion of the temporal bone, and from it three large trunks arise—the ophthalmic or first, the superior maxillary or second, and the inferior maxillary or third divisions of the nerve. The small motor root of the nerve passes forward beneath the Gasserian ganglion, and is wholly incorporated with the inferior maxillary division of the nerve.

Ophthalmic Division (n. ophthalmicus).—The ophthalmic nerve passes forwards to the orbit through the middle fossa of the base of the skull, beneath the dura mater. It lies in the outer wall of the cavernous sinus, at a lower level than the fourth nerve, and reaches the orbit through the sphenoidal fissure (Fig. 520).

In the wall of the cavernous sinus the ophthalmic nerve gives off (1) a small recurrent branch to the dura mater (n. tentorii), (2) communicating branches to the cavernous plexus of the sympathetic on the internal carotid artery, and (3) small communicating twigs to the trunks of the third, fourth, and sixth nerves.

In the sphenoidal fissure the nerve divides into three main branches—lachrymal, frontal, and nasal (Fig. 524).

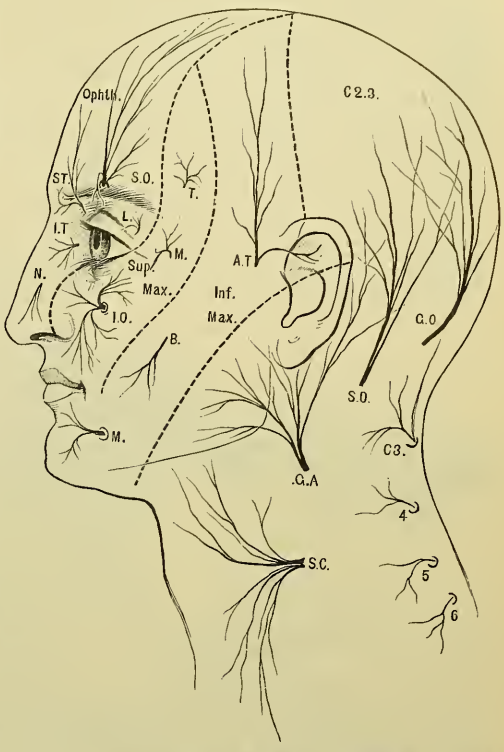


Fig. 523.—Distribution of Sensory Nerves to the Head and Neck.

Ophth, Ophthalmic division of the fifth nerve ; St, Supra-trochlear branch ; S.O, Supra-orbital branch ; I.T, Infra-trochlear branch ; L, Lachrymal branch ; N, External nasal branch ; Sup.Max, Superior maxillary division ; T, Temporal branch ; M, Malar branch ; I.O, Infra-orbital branch ; Inf.Max, Inferior maxillary division ; A.T, Auriculo-temporal branch ; B, Buccal branch ; M, Mental branch ; C2, 3, Branches of the second and third cervical nerves ; G.O, Great occipital nerve ; S.O, Small occipital nerve ; G.A, Great auricular nerve ; S.C, Superficial cervical nerve ; C3, Least occipital nerve ; 4, 5, 6, Posterior primary division of 4th, 5th, and 6th cervical nerves.

The **lachrymal nerve** (n. lacrymalis) enters the orbit through the outer angle of the sphenoidal fissure, above the orbital muscles. Passing forwards beneath the periosteum to the anterior part of the orbit, the nerve ends by supplying branches (*a*) to the lachrymal gland, (*b*) to the conjunctiva, and (*c*) to the skin of the outer canthus of the eye.

The lachrymal nerve *communicates* in the orbit with the orbital branch of the superior maxillary nerve, and on the face, by its terminal branches, with the temporal branches of the facial nerve (Fig. 523).

The **frontal nerve** (n. frontalis), entering the orbital cavity through the sphenoidal fissure, courses forwards above the ocular muscles, and divides at a variable point into two branches—a larger supra-orbital and a smaller supra-trochlear nerve. The **supra-orbital nerve** (n. supra-orbitalis) passes directly forwards, and leaves the orbit through the supra-orbital groove or foramen to reach the forehead. It gives off the following secondary branches: (1) the principal branches (rr. frontales) are distributed to the forehead and scalp, reaching backwards as far as the vertex ; (2) small branches supply the upper eyelid ; and (3) twigs are distributed to the frontal sinus. On the forehead the supra-orbital nerve communicates with the temporal branches of the facial nerve. The **supra-trochlear nerve** (n. supra-trochlearis) courses obliquely forwards and inwards over the tendon

of the superior oblique muscle to reach the inner side of the supra-orbital arch. Leaving the cavity of the orbit, the nerve is distributed to the skin of the mesial part of the forehead, the root of the nose, and the inner canthus of the eye.

It *communicates* with the infra-trochlear branch of the nasal nerve, either before or after leaving the orbital cavity.

The **nasal nerve** (n. naso-ciliaris) enters the orbit through the sphenoidal fissure, between the heads of the external rectus muscle, and between the two divisions of the third nerve (Fig. 520, p. 677). It crosses the orbital cavity obliquely to reach the anterior ethmoidal foramen, lying in its course below the superior rectus and superior oblique muscles, and above the optic nerve and internal rectus muscle. The nerve is transmitted through the anterior ethmoidal foramen into the cranial cavity, where it lies on the cribriform plate of the ethmoid bone. It enters the nasal cavity through the nasal fissure, and terminates by dividing into internal and external branches. The internal division supplies the mucous membrane over the upper and anterior part of the nasal septum (rr. mediales). The external branch, after supplying collateral offsets to the outer wall of the nose (rr. laterales), finally appears on the face between the nasal bone and lateral cartilage, and supplies branches to the skin of the lower part and tip of the nose.

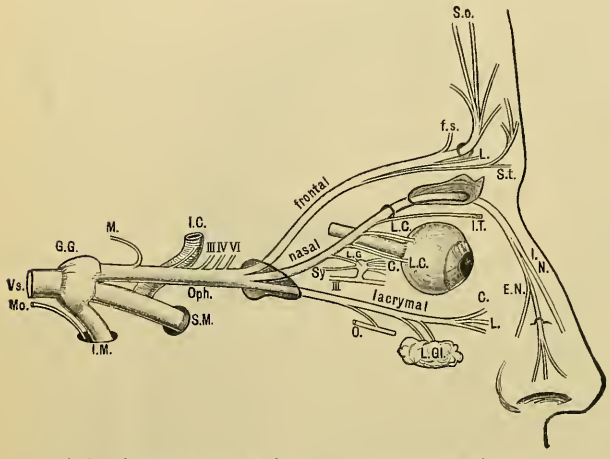


FIG. 524.—SCHEME OF THE DISTRIBUTION OF THE OPHTHALMIC NERVE.

Vs, Trigeminal nerve, afferent root; Mo, Efferent root; G.G, Gasserian ganglion; M, Meningeal branch; I.C, Branch to internal carotid artery; Oph, Ophthalmic nerve; S.M, Superior maxillary nerve; I.M, Inferior maxillary nerve; III, Communication to oculo-motor nerve; IV, To trochlear nerve; VI, To abducent nerve. Frontal nerve; f.s, Branches to frontal sinus; S.o, Supra-orbital nerve; S.t, Supra-trochlear nerve; L, Branches to upper eyelid. Nasal nerve; L.G, Long root to lenticular ganglion; Sy, Root from sympathetic (on carotid artery); III, Short root from motor oculi nerve; C, Short ciliary branches; L.C, Long ciliary nerves; I.T, Infra-trochlear nerve; E.N, External, and I.N, Internal nasal nerves. Lachrymal nerve; O, Orbital branch of superior maxillary nerve; L.Gl, Lachrymal gland; C, Conjunctival branch; L, Branch to eyelids and face.

The **branches** of the nasal nerve may be divided into three sets, arising (*a*) in the orbit, (*b*) in the nose, and (*c*) on the face.

In the orbit the branches are given off in three situations—external to, over, and internal to the optic nerve. (*a*) As the nasal nerve lies external to the optic nerve, it gives off the **long root of the ciliary ganglion** (radix longa). (*b*) As it crosses the optic nerve **two long ciliary branches** (nn. ciliaris longi) arise, and pass forwards alongside the optic nerve to the eyeball. (*c*) On the inner side of the optic nerve the **infra-trochlear nerve** (n. infra-trochlearis) arises, a slender branch which courses forward beneath the pulley of the superior oblique muscle to the front of the orbit. It ends on the face by supplying the skin of the root of the nose and the eyelids, and communicates either in the orbit or on the face with the supra-trochlear nerve. On the face it also communicates with infra-orbital branches of the facial nerve.

In the nose the **internal nasal branch** supplies the mucous membrane of the fore-part of the nasal septum; the **external nasal branch** supplies the fore-part of the outer wall of the nose.

On the face the terminal filaments of the nerve are distributed to the skin of the lower half and tip of the nose. The superficial terminal branch communicates with the infra-orbital branches of the facial nerve (Fig. 523).

The **ciliary** or **lenticular ganglion** (ganglion ciliare) is associated with the nasal branch of the ophthalmic nerve and with the lower division of the third nerve. It is a small reddish ganglion, placed between the external rectus muscle

and the optic nerve, and in front of the ophthalmic artery. Its *roots* are three in number: (1) **sensory** or long (radix longa), derived from the nasal branch of the ophthalmic nerve; (2) **motor** or short (radix brevis), derived from the inferior division of the third nerve; and (3) **sympathetic**, a slender filament from the cavernous plexus on the internal carotid artery, which may exist as an independent root or may be incorporated with the long root from the nasal nerve. The branches from the ganglion are twelve to fifteen **short ciliary nerves** (nn. ciliares breves), which pass to the eyeball in two groups above and below the optic nerve. They supply the coats of the eyeball, including the iris and ciliary muscles. *The circular fibres of the iris* and the *ciliary muscle* are innervated by the third nerve; *the radial fibres of the iris* by the sympathetic.

Superior Maxillary Division of the Fifth Nerve (n. maxillaris).—This large nerve courses forwards from its origin in the Gasserian ganglion through the middle fossa of the base of the skull, beneath the dura mater, and in relation to the lower part of the cavernous sinus (Fig. 520, p. 677). Passing through the foramen rotundum in the root of the pterygoid process, it traverses the spheno-maxillary fossa. It enters the orbit as the infra-orbital nerve, through the spheno-maxillary

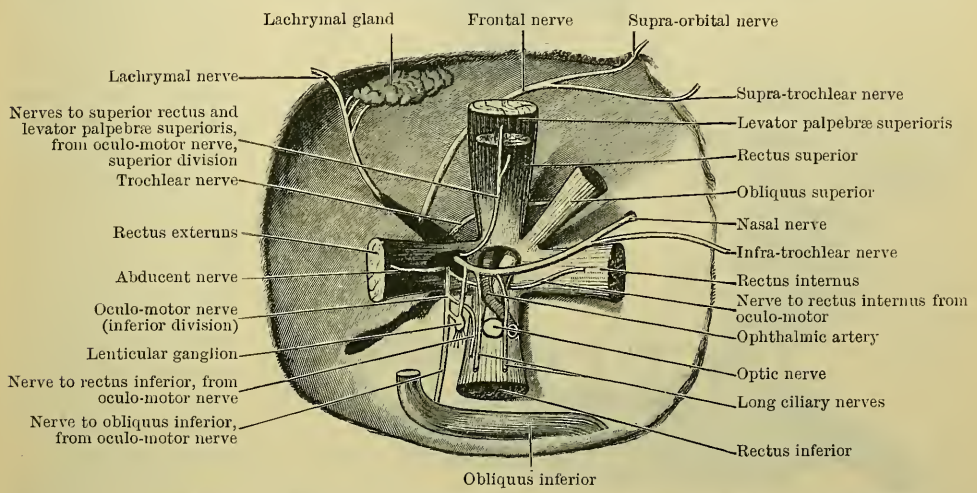


FIG. 525.—SCHEMATIC REPRESENTATION OF THE NERVES WHICH TRAVERSE THE CAVITY OF THE ORBIT.

fissure, and occupying successively the infra-orbital groove and canal, it finally appears on the face through the infra-orbital foramen (Fig. 526).

The branches and communications of this nerve occur (*a*) in the cavity of the cranium, (*b*) in the spheno-maxillary fossa, (*c*) in the infra-orbital canal, and (*d*) on the face.

In the cavity of the cranium the nerve gives off a minute **recurrent branch** (n. meningeus) to the dura mater of the middle fossa of the base of the skull.

In the spheno-maxillary fossa the nerve gives off—(1) two short thick **spheno-palatine nerves** (nn. spheno-palatini), the short or sensory roots of the spheno-palatine (Meckel's) ganglion. (2) A **posterior dental nerve**, which may be double (nn. alveolares superiores), descends through the pterygo-maxillary fissure to the outer side of the upper jaw, and proceeds forwards along the alveolar arch, in company with the posterior dental artery. It supplies the gum and the upper molar teeth by branches which perforate the bone to reach the alveoli. The nerve forms a fine plexus joined by the middle dental nerve before finally reaching the teeth. (3) A small **orbital branch** (n. zygomaticus) enters the orbital cavity through the spheno-maxillary fissure, and proceeding along the outer wall, communicates with the lachrymal nerve, and passes through the orbital canal in the malar bone, where it divides into malar and temporal branches. The **malar branch** (n. zygomatico-facialis) appears on the face, after traversing the malar bone, and supplies the skin over that bone. It communicates with the malar branches of the facial nerve. The **temporal branch** (n. zygomatico-temporalis) perforates the zygomatic

surface of the malar bone, and is distributed, after piercing the temporal fascia, to the skin over the fore-part of the temple. It communicates with the temporal branches of the facial nerve. It may be very minute, and not pass further than the temporal fascia, between the two layers of which it may form a communication with the facial nerve. (4) The **infra-orbital nerve** (n. infra-orbitalis) is the terminal branch of the superior maxillary nerve, which enters the orbit through the spheno-maxillary fissure and traverses the infra-orbital canal to reach the face.

In the infra-orbital canal the infra-orbital nerve supplies one and sometimes two branches to the teeth—the **middle** and **anterior dental nerves** (rr. alveolares superiores medius and anterior). The former may be only a secondary branch of the latter nerve, or they may arise independently from the infra-orbital nerve. However formed, the nerves descend in bony canals in the wall of the antrum of Highmore (to the lining of which branches are given), and reach the alveolar arch, where they form minute plexuses and supply the teeth (joining posteriorly with the branches of the posterior dental nerve). The anterior dental nerve supplies the incisor and canine teeth; the middle dental nerve supplies the premolar teeth.

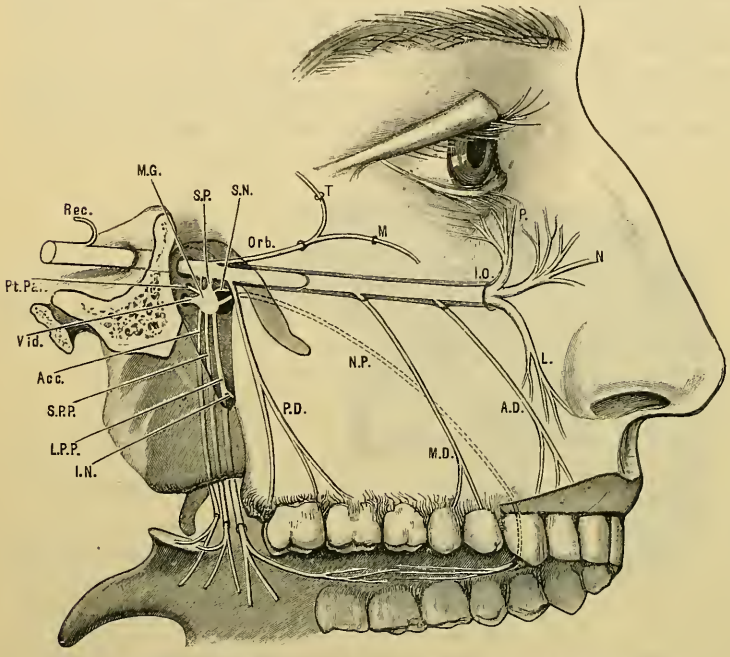


FIG. 526.—SCHEME OF THE COURSE AND DISTRIBUTION OF THE SUPERIOR MAXILLARY NERVE.

Rec, Recurrent branch in the middle fossa of the skull; M.G, Meckel's ganglion in the spheno-maxillary fossa; S.P, Spheno-palatine nerves; S.N, Superior nasal branch; Orb, Orbital nerve; T, Temporal, and M, Malar branches; I.O, Infra-orbital nerve, appearing on the face; P, Palpebral; N, Nasal, and L, Labial branches; A.D, Anterior dental branch; M.D, Middle dental branch; N.P, Naso-palatine nerve; P.D, Posterior dental branch; I.N, Inferior nasal branch; L.P.P, Large posterior palatine nerve; S.P.P, Small posterior palatine nerve; Acc, Accessory posterior palatine nerve; Vid, Vidian nerve; Pt.Pal, Pterygo-palatine branch.

After emerging on the face from the infra-orbital foramen, the infra-orbital nerve divides into a number of radiating branches arranged in three sets—(*a*) **palpebral**, for the lower eyelid; (*b*) **nasal**, for the skin of the side of the nose; and (*c*) **labial**, for the cheek and upper lip. These branches form communications with the infra-orbital branches of the facial nerve, and give rise to the *infra-orbital plexus* (Fig. 523, p. 679).

The **spheno-palatine** or **Meckel's ganglion** (g. spheno-palatinum) occupies the upper part of the spheno-maxillary fossa. It is a small reddish-gray ganglion, suspended from the superior maxillary nerve by the two **spheno-palatine branches** which constitute its sensory roots. The **motor** and **sympathetic roots** of the ganglion are derived from the **vidian nerve**. This nerve is formed in the cavity of the skull upon the cartilage filling up the foramen lacerum medium, by the union of the *great superficial petrosal nerve* from the geniculate ganglion of the facial nerve (emerging from the temporal bone through the hiatus Fallopii) with the *great deep petrosal nerve*, a branch of the carotid plexus of the sympathetic on the internal carotid artery. The vidian nerve passes through the vidian canal to the spheno-maxillary fossa, where it ends in Meckel's ganglion.

The **branches from the ganglion** are seven in number. (*a*) The **pterygo-palatine** or **pharyngeal** branch passes backwards through the pterygo-palatine canal to supply the mucous membrane of the roof of the pharynx.

(*b*) The **posterior palatine nerves**, three in number, are directed downwards to the palate through the posterior palatine canals. The **large posterior palatine nerve** emerges on the under surface of the palate through the large posterior palatine canal, and at once separates into numerous branches for the supply of the mucous membrane of the soft and the hard palate. Its anterior filaments communicate with branches of the naso-palatine nerve. The main nerve gives off, as it lies in the posterior palatine canal, a small **inferior nasal nerve** which enters the nasal cavity and supplies the mucous membrane of the lower part of the outer wall of the nose. The **small posterior palatine nerve** descends through the small posterior palatine canal, and, piercing the tuberosity of the palate bone, is distributed to the mucous membrane of the soft palate, uvula, and tonsil. It possibly conveys motor fibres to the levator palati and azygos uvulæ muscles. The **accessory posterior palatine nerves** are one or more small twigs which pass through accessory posterior palatine canals, and supply branches to the mucous membrane of the tonsil, soft palate, and uvula.

(*c*) The branches directed inwards from Meckel's ganglion enter the nasal cavity through the spheno-palatine foramen. They are two in number—the superior nasal and the naso-palatine. The **superior nasal nerve** is a small nerve destined for the mucous membrane of the upper and back part of the outer wall of the nose. The **naso-palatine nerve**, after passing through the spheno-palatine foramen, crosses the roof of the nose, and extends obliquely downwards and forwards along the nasal septum, grooving the vomer in its course, to reach the incisor foramen near the front of the hard palate. The nerves pass through the subordinate mesial foramina (of Scarpa), the left nerve in front of the right. In the incisor foramen the two nerves communicate together. They then turn backwards and supply the mucous membrane of the hard palate. They communicate posteriorly with terminal filaments of the large posterior palatine nerves. In its course through the nasal cavity the naso-palatine nerve furnishes collateral branches to the mucous membrane of the roof and septum of the nose (Fig. 518, p. 676).

(*d*) The **orbital branches**, one or more minute branches, pass upwards to the periosteum of the orbit from Meckel's ganglion.

Inferior Maxillary Nerve (n. mandibularis).—The inferior maxillary nerve is formed by the union of two roots: a large **sensory root**, from the Gasserian ganglion, and the small **motor root** of the trigeminal nerve, which is wholly incorporated with this trunk. The two roots pass together beneath the dura mater of the middle fossa of the base of the skull to the foramen ovale, through which they emerge into the pterygoid region. Outside the skull they combine to form a single trunk, which soon separates into anterior and posterior divisions.

At its emergence from the skull the nerve is deeply placed beneath the middle of the zygomatic arch, and is concealed by the ramus of the lower jaw, and by the temporal, masseter, and external pterygoid muscles.

The branches of the inferior maxillary nerve may be divided into two series—(1) those derived from the undivided nerve, and (2) those derived from the terminal divisions of the nerve.

The branches of the undivided nerve are two in number. (*a*) A small **recurrent branch** (n. spinosus) arises just outside the skull, and accompanying the middle meningeal artery through the foramen spinosum, supplies the dura mater. (*b*) In the pterygoid region a small branch arises for the supply of the **internal pterygoid muscle**. This nerve forms a connexion with the otic ganglion.

The terminal divisions of the nerve are a small anterior and a large posterior trunk.

The small **anterior trunk** passes downwards and forwards beneath the external pterygoid muscle, and separates into the following branches:—(1) A branch for the external pterygoid muscle (n. pterygoideus externus), which supplies it on its deep surface; (2) a branch to the masseter muscle (n. massetericus), which passes over the upper border of the external pterygoid and through the sigmoid notch of the lower jaw; (3) and (4) two branches to the temporal muscle (nn. temporales pro-

fundi, anterior et posterior), which also ascend above the external pterygoid muscle; and (5) the **buccal nerve** (n. buccinatorius), which passes obliquely forwards between the two heads of the external pterygoid to reach the buccinator muscle. This nerve is sensory, and its fibres are in part distributed to the skin of the cheek (communicating with buccal branches of the facial nerve); they are also in part distributed to the mucous membrane of the inside of the mouth, to reach which they pierce the fibres of the buccinator muscle. The buccal nerve usually supplies a third branch to the temporal muscle, after emerging between the two heads of the external pterygoid muscle (Fig. 523, p. 679).

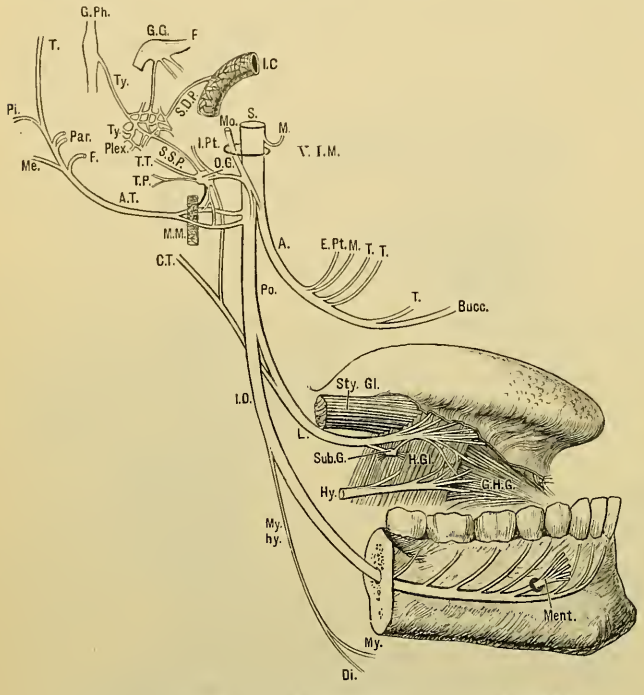


FIG. 527.—SCHEME OF THE DISTRIBUTION OF THE INFERIOR MAXILLARY NERVE.

V.I.M, Inferior maxillary nerve; S, Afferent, and Mo, Efferent roots; M, Meningeal branch; O.G, Otic ganglion; I.Pt, Nerve to internal pterygoid; S.S.P, Small superficial petrosal nerve; T.T, Nerves to tensor tympani, and T.P, Tensor palati; Ty.Plex, Tympanic plexus; I.C, Internal carotid artery; S.D.P, Small deep petrosal nerve; G.G, Geniculate ganglion; F, Facial nerve; Ty, Tympanic branch; G.Ph, Glosso-pharyngeal nerve; M.M, Middle meningeal artery; A.T, Auriculo-temporal nerve; F, Communication with facial nerve; Par, Nerve to parotid gland; Me, Branch to meatus of ear; Pi, Branch to pinna; T, Temporal branch; A, Anterior division of inferior maxillary nerve; E.Pt, Nerves to external pterygoid; M, Masseter; T.T.T, Temporal, and Bucc, Buccinator muscles; Po, Posterior division of inferior maxillary nerve; L, Lingual nerve; C.T, Chorda tympani nerve; Sub.G, Sub-maxillary ganglion; Hy, Hypoglossal nerve; I.D, Inferior dental nerve; My.hy, Mylohyoid nerve; My, Nerve to mylohyoid; Di, Nerve to digastric (anterior belly); Ment., Mental Branch; Sty.Gl, Stylo-glossus; H.Gl, Hyoglossus; G.H.G, Genio-hyoglossus muscles.

The large **posterior trunk** extends downwards a short way beneath the external pterygoid muscle. After giving off by two roots the auriculo-temporal nerve, it ends by dividing into two, the lingual and the inferior dental nerves.

The **auriculo-temporal nerve** (n. auriculo-temporalis) is formed by the union of two roots which embrace the middle meningeal artery. The nerve passes backwards beneath the external pterygoid muscle and between the internal lateral ligament and the neck of the lower jaw. Entering the substance of the parotid gland, it is directed upwards to the temple over the zygoma in company with the temporal artery. It is finally distributed as a cutaneous nerve of the temple and scalp, and reaches almost to the vertex of the skull.

The auriculo-temporal nerve gives off the following branches:—(1) A small branch to the temporo-maxillary articulation. (2) Branches to the parotid gland. (3) A twig for the supply of the skin of the external auditory meatus (and membrana tympani). (4) Branches to the upper half of the pinna on its outer aspect. (5) Terminal branches to the skin of the temple and scalp.

It has the following **communications** with other nerves:—(1) Important communications are effected by the roots of the nerve, which are separately joined by small branches from the otic ganglion. (2) The parotid branches of the nerve are connected with branches of the facial nerve in the substance of the gland. (3) The temporal branch of the nerve is in communication superficially with the temporal branches of the facial nerve.

The **lingual nerve** (n. lingualis) is the smaller of the two terminal branches

of the posterior division of the inferior maxillary nerve. It proceeds downwards in front of the inferior dental nerve, beneath the external pterygoid muscle, to its lower border. After passing between the internal pterygoid muscle, and the ramus of the lower jaw, it crosses beneath the mucous membrane of the floor of the mouth in the interval between the mylohyoid and hyoglossus muscles and beneath the duct of the submaxillary gland. It sweeps forwards and inwards to the side of the tongue, to the mucous membrane over the anterior two-thirds of which it is distributed.

Two nerves communicate with the lingual nerve in its course to the tongue :— (1) The **chorda tympani branch** of the facial nerve joins it beneath the external pterygoid muscle, and is incorporated with it in its distribution to the tongue. (2) The **hypoglossal nerve** forms larger or smaller loops of communication with the lingual nerve as they course forwards together over the hyoglossus muscle.

Besides supplying the aforesaid branches to the mucous membrane over the sides and dorsum of the tongue in its anterior two-thirds, the lingual nerve supplies the mucous membrane of the outer wall and floor of the mouth. It also assists, along with the chorda tympani nerve, in forming the roots of the submaxillary ganglion.

The **submaxillary ganglion** (ganglion submaxillare) is a minute reddish ganglion placed on the hyoglossus muscle, between the lingual nerve and the duct of the submaxillary gland. It is suspended from the former by two trunks, consisting for the most part of fibres of the lingual and chorda tympani nerves which at this point become separated from the lingual nerve and incorporated with the ganglion. The **roots** of the ganglion are—(1) an afferent root, derived from the lingual nerve ; (2) an efferent root, derived from the chorda tympani ; and (3) a sympathetic root, from the sympathetic plexus upon the facial artery.

The **branches from the ganglion** are distributed to the submaxillary gland and Wharton's duct, and by fibres which become reunited with the trunk of the lingual nerve, to the sublingual gland.

The **inferior dental nerve** (n. alveolaris inferior) is larger than the lingual nerve. It passes from beneath the lower border of the external pterygoid muscle to reach the interval between the ramus and internal lateral ligament of the lower jaw. Entering the inferior dental canal through the inferior dental foramen, it traverses the substance of the ramus and body of the lower jaw, distributing branches in its course to the teeth. A fine plexus is formed by the dental branches before they finally supply the teeth.

Branches and Communications.—(1) The **mylohyoid nerve** is a small branch arising just before the inferior dental nerve passes through the inferior dental foramen. Grooving the ramus of the jaw in its course, it descends into the submaxillary triangle on the superficial aspect of the mylohyoid muscle. Concealed in this situation by the submaxillary gland and the facial artery, it is distributed to the mylohyoid and anterior belly of the digastric muscles. (2) The **mental branch** of the inferior dental nerve is a trunk of considerable size arising from the main nerve in the inferior dental canal. It emerges from the lower jaw through the mental foramen, and is distributed by many branches to the chin and lower lip. It communicates beneath the facial muscles with the supra-mandibular branches of the facial nerve (Fig. 523, p. 679). (3) The **incisor branch** is the terminal part of the inferior dental nerve remaining after the origin of the mental branch. It supplies the incisor and canine teeth.

The **otic ganglion** (g. oticum) is situated beneath the inferior maxillary nerve just below the foramen ovale. Like the other ganglia described above, it possesses three roots :—(1) A *motor root,* derived from the nerve to the internal pterygoid muscle ; (2) a *sensory root,* formed by the *small superficial petrosal nerve* from the tympanic plexus (through which communications are effected with the tympanic branch of the glosso-pharyngeal nerve, and a branch from the geniculate ganglion of the facial nerve); (3) a *sympathetic root,* from the plexus on the middle meningeal artery (Fig. 527).

Five branches arise from the ganglion—three communicating and two motor branches. The three **communicating nerves** are fine branches which join respectively

the vidian nerve, the roots of the auriculo-temporal, and the chorda tympani nerve. The two **motor nerves** supply the tensor tympani and tensor palati muscles.

Summary.—The trigeminal, the largest and most complex of the cranial nerves, is (1) the chief sensory nerve for the face, the anterior half of the scalp, the orbit and eyeball, the nose and nasal cavity, the lips, teeth, mouth, and two-thirds of the tongue; (2) the motor fibres of the nerve supply the muscles of mastication, the mylohyoid and anterior belly of the digastric, possibly the levator palati and azygos uvulæ (through Meckel's ganglion), and the tensor tympani and tensor palati muscles (through the otic ganglion); (3) through the ganglia placed on the three divisions of the nerve, not only are important organs, areas, and muscles innervated, but communications are also effected with the sympathetic system, with the third nerve (lenticular ganglion), facial nerve (spheno-palatine and otic ganglia), and glosso-pharyngeal nerve (otic ganglion).

In its distribution to the skin of the face the branches of the fifth nerve present two striking peculiarities:—(1) While the branches to the skin reach the surface at many points and in diverse ways, the three main divisions are severally, by their branches, responsible for the supply of three clearly demarcated cutaneous areas (Fig. 523, p. 679). (2) By numerous communications with the facial nerve, sensory fibres are given to the muscles of expression supplied by the facial nerve.

The Sixth or Abducent Nerve.

The abducent nerve (n. abducens) issues from the brain at the lower border of the pons Varolii, just above the pyramid of the medulla oblongata (for deep origin, see p. 524). It is directed forwards, and pierces the dura mater in the posterior fossa of the base of the skull alongside the dorsum sellæ (Fig. 522, p. 678). It then occupies the inner wall of the cavernous sinus and is placed on the outer side of the internal carotid artery. It passes through the sphenoidal fissure below the third and nasal nerves and between the two heads of the external rectus muscle (Fig. 520, p. 677). In the cavity of the orbit it supplies the external rectus muscle on its inner (ocular) surface.

Communications.—In the wall of the cavernous sinus the sixth nerve receives two communicating filaments:—(1) From the carotid plexus of the sympathetic, and (2) from the ophthalmic division of the trigeminal nerve.

The Seventh or Facial Nerve.

The facial nerve (n. facialis) emerges from the brain at the posterior border of the pons Varolii, below the trigeminal nerve and internal to the auditory nerve (for deep origin, see p. 522). Between it and the latter nerve is the minute **pars intermedia** of Wrisberg (Fig. 517, p. 675). The nerve passes outwards through the internal auditory meatus, courses through the aqueduct of Fallopius in the petrous portion of the temporal bone, emerges in the base of the skull by the stylo-mastoid foramen, and passes forwards through the parotid gland to supply the muscles of the face. *In the internal auditory meatus* the nerve is placed upon the auditory nerve, the *pars intermedia* intervening. *In the aqueduct of Fallopius* the nerve first passes backwards on the inner side of the tympanum, and then downwards behind the tympanum, in the inner wall of the tympanic antrum. *In the parotid gland* the nerve crosses superficially the external carotid artery and the temporo-maxillary vein. *On the face* its branches radiate from the anterior border of the parotid gland and enter the deep surface of the facial muscles.

Branches and Communications.—(i.) *In the internal auditory meatus* the *pars intermedia* (n. intermedius), lying between the facial and auditory, sends communicating branches to both nerves. The branch to the auditory nerve probably separates from it again to join the geniculate ganglion of the facial nerve.

(ii.) *In the aqueduct of Fallopius* the **geniculate ganglion** (g. geniculi) is formed at the point where the facial nerve bends backwards (geniculum n. facialis). It is an oval swelling on the nerve, and is joined by a branch from the upper (vestibular) trunk of the auditory nerve, by which it probably receives fibres of the *pars intermedia*. From the ganglion three small nerves arise:—(1) The **large superficial petrosal nerve** passes forwards through the hiatus Fallopii to the middle fossa of the base of the skull. On the upper surface of the foramen lacerum medium it is

joined by the **great deep petrosal nerve** from the sympathetic plexus on the internal carotid artery to form the **vidian nerve**, which, after traversing the vidian canal, ends in Meckel's ganglion. (2) A minute nerve pierces the temporal bone and joins the tympanic branch of the glosso-pharyngeal in the substance of the bone. By their union the **small superficial petrosal nerve** is formed, which pierces the temporal bone and ends in the otic ganglion. (3) The **external superficial petrosal nerve** is a minute inconstant branch which joins the sympathetic plexus on the middle meningeal artery.

In the course of the facial nerve in the lower part of the aqueduct of Fallopius, behind the tympanum, three branches arise—(1) The small nerve to the **stapedius muscle**, which passes forwards to the tympanum. (2) The **chorda tympani nerve** (probably associated with the *pars intermedia*), which enters the tympanic cavity through the *iter chordæ posterius*, passes over the membrana tympani and the handle of the malleus, and leaves the cavity through the *iter chordæ anterius* to reach the pterygoid region. Beneath the external pterygoid muscle it becomes incorporated with the lingual branch of the inferior maxillary nerve, and in its further course is inseparable from that nerve. It supplies a root to the sub-maxillary ganglion, and is finally distributed (probably as a nerve of taste) to the side and dorsum of the tongue in its anterior two-thirds. The chorda tympani nerve receives beneath the external pterygoid muscle a fine communication from the otic ganglion. (3) Before it leaves the aqueduct of Fallopius a fine **communicating branch** arises from the facial nerve to join the auricular branch of the pneumogastric nerve.

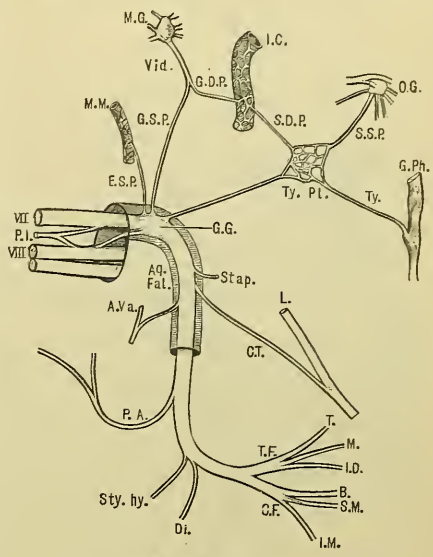


FIG. 528.— THE FACIAL NERVE WITH ITS BRANCHES AND COMMUNICATIONS IN THE AQUEDUCT OF FALLOPIUS.

VII, Facial nerve; P.I, Pars intermedia; VIII, Auditory nerve; Aq.Fal, Aqueduct of Fallopius; G.G, Geniculate ganglion; E.S.P, External superficial petrosal nerve; M.M, Middle meningeal artery; G.S.P, Great superficial petrosal nerve: G.P.D, Great deep petrosal nerve; I.C, Internal carotid artery; Vid, Vidian nerve; M.G, Meckel's ganglion; Ty.Pl, Tympanic plexus; S.D.P, Small deep petrosal nerve; G.Ph, Glosso-pharyngeal nerve; Ty, Tympanic branch; S.S.P, Small superficial petrosal nerve; O.G, Otic ganglion; Stap, Nerve to stapedius; C.T, Chorda tympani nerve; L, Lingual nerve; A.Va, Communication with auricular branch of vagus; P.A, Posterior auricular nerve; Sty.hy, Nerve to stylo-hyoid; Di, Nerve to digastric (posterior belly); T.F, Temporo-facial division; C.F, Cervico-facial division; T. Temporal; M, Malar; I.O, Infra-orbital; B. Buccal; S.M, Supra-mandibular, and I.M, Infra-mandibular branches.

(iii.) *In the neck* the facial nerve gives off three muscular branches: (1) and (2) small branches supply the stylo-hyoid and the posterior belly of the digastric, the latter nerve sometimes communicating with the glosso-pharyngeal. (3) The **posterior auricular nerve** bends backwards and upwards over the anterior border of the mastoid process along with the posterior auricular artery. It divides into two branches—an *auricular branch* for the retrahens aurem and the intrinsic muscles of the pinna, and an *occipital branch* for the posterior belly of the occipito-frontalis muscle. The posterior auricular nerve communicates with the great auricular, small occipital, and auricular branch of the pneumogastric nerves in its course.

(iv.) *In the parotid gland* the facial nerve spreads out in an irregular series of branches (**pes anserinus**), indefinitely divided into a temporo-facial and a cervico-facial division. Communications occur in the substance of the gland between the main trunks and the great auricular and auriculo-temporal nerves.

The **temporo-facial division** gives off three series of subordinate branches which radiate forwards and upwards from the parotid gland.

1. The **temporal branches** are of large size, and, sweeping out of the parotid gland over the zygomatic arch, are distributed to the orbicularis palpebrarum, frontalis, corrugator supercilii, attrahens, and attollens aurem. The temporal branches com-

municate in their course with the auriculo-temporal, temporal (of the superior maxillary), lachrymal, and supra-orbital branches of the trigeminal nerve.

2. The **malar branches** are small, and sometimes are inseparable from the temporal or infra-orbital nerves. Extending forwards across the malar bone, they supply the orbicularis palpebrarum and zygomatic muscles, and communicate with the malar branch of the superior maxillary nerve.

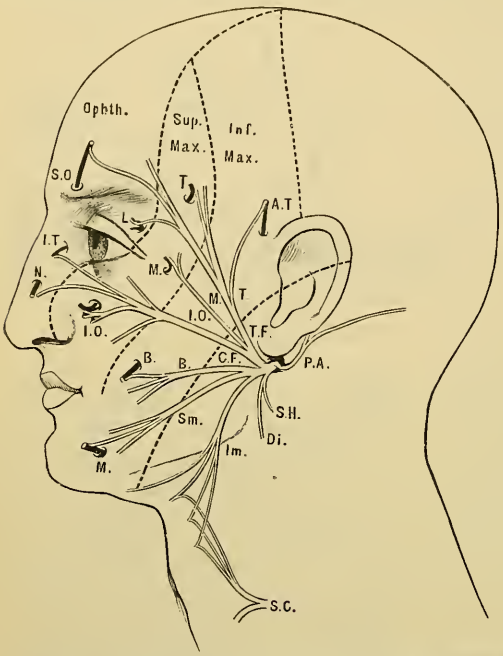


FIG. 529.—DISTRIBUTION OF FACIAL NERVE OUTSIDE THE SKULL, AND COMMUNICATIONS WITH TRIGEMINAL NERVE ON THE FACE.

Facial nerve. — P.A, Posterior auricular nerve; S.H, Nerve to stylo-hyoid; Di, Nerve to digastric (posterior belly); T.F, Temporo-facial division; T, Temporal; M, Malar; I.O, Infra-orbital branches; C.F, Cervico-facial division; B, Buccal; Sm, Supra-mandibular; Im, Infra-mandibular branches.

Trigeminal nerve.—Ophth, Ophthalmic division; S.O, Supra-orbital; I.T, Infra-trochlear; N, External nasal; L, Lachrymal branches. Sup. Max, Superior maxillary division; T, Temporal; M, Malar; I.O, Infra-orbital branches. Inf. Max, Inferior maxillary division; A.T, Auriculo-temporal; B, Buccal; M, Mental branches; S.C, Superficial cervical nerve.

3. The **infra-orbital branches** are of considerable size. Passing forwards over the masseter muscle in company with Stenson's duct, they supply the orbicularis palpebrarum, the zygomatici, buccinator, and the muscles of the nose and upper lip. The **infra-orbital plexus** is formed by the union of these nerves with the infra-orbital branch of the superior maxillary nerve below the lower eyelid. Smaller communications occur with the infra-trochlear and nasal nerves on the side of the nose.

The **cervico-facial division** of the facial nerve also supplies three series of secondary branches.

1. The **buccal branch** (or branches) extends forwards to the angle of the mouth to supply the muscles converging to the mouth, including the buccinator. It communicates with the buccal branch of the inferior maxillary nerve in front of the anterior border of the masseter muscle.

2. The **supra-mandibular branch** passes along the lower jaw to the interval between the lower lip and chin, and supplies the depressor anguli oris, depressor labii inferioris, and orbicularis oris. It communicates with the mental branch of the inferior dental nerve.

3. The **infra-mandibular branch** emerges from the parotid gland near its lower end, and sweeps forwards below the angle of the jaw to the front of the neck. It supplies the platysma myoides, and forms loops of communication with the superficial cervical nerve from the cervical plexus.

THE EIGHTH OR AUDITORY NERVE.

The auditory nerve (n. acusticus) arises from the brain by two roots, mesial and lateral. The **mesial root** (radix vestibularis) emerges between the olive and the restiform body. The **lateral root** (radix cochlearis), continuous through the cochlear nucleus with the striæ acusticæ of the fourth ventricle, winds round the outer side of the restiform body (for deep connexions, see p. 519). The two roots become incorporated to form the trunk of the nerve, which is attached to the brain on the outer side of the facial nerve and pars intermedia at the posterior border of the pons Varolii (Fig. 517, p. 675).

The nerve extends outwards through the internal auditory meatus, lying beneath the facial nerve and pars intermedia (Fig. 522, p. 678). In the meatus its two component parts separate from one another, forming a superior or vestibular trunk continuous with the mesial root, and an inferior or cochlear trunk continuous with

the lateral root. These trunks again subdivide, and piercing the lamina cribrosa, supply the several parts of the labyrinth.

The **superior** or **vestibular trunk** (n. vestibuli) in the internal auditory meatus usually receives fibres from the *pars intermedia*, and gives off a communicating branch

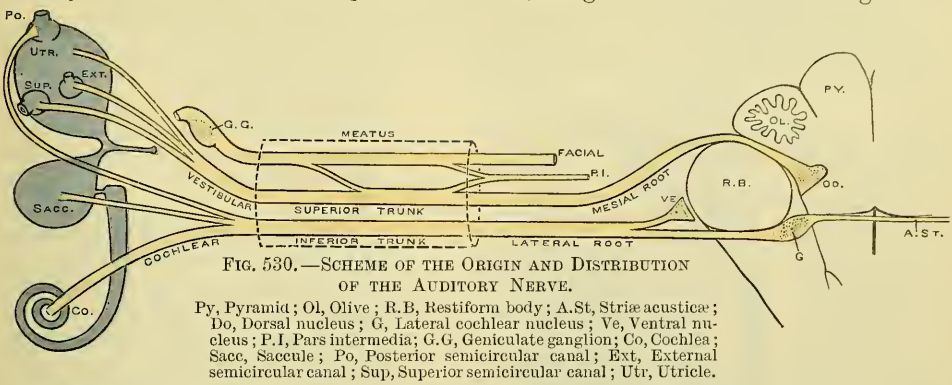


FIG. 530.—SCHEME OF THE ORIGIN AND DISTRIBUTION OF THE AUDITORY NERVE.

Py, Pyramid; Ol, Olive; R.B, Restiform body; A.St, Striæ acusticæ; Do, Dorsal nucleus; G, Lateral cochlear nucleus; Ve, Ventral nucleus; P.I, Pars intermedia; G.G, Geniculate ganglion; Co, Cochlea; Sacc, Saccule; Po, Posterior semicircular canal; Ext, External semicircular canal; Sup, Superior semicircular canal; Utr, Utricle.

to the geniculate ganglion of the facial nerve. It then separates into three terminal branches which pierce the lamina cribrosa, and supply (1) the macula acustica of the **utricle** and the ampullæ of (2) the **superior** and (3) **external semicircular canals.**

The **inferior** or **cochlear trunk** (n. cochleæ) gives off branches (1) to the macula acustica of the **saccule**, (2) to the ampulla of the **posterior semicircular canal**, and (3) is continued through the lamina cribrosa to the labyrinth as the **cochlear nerve**, which is distributed through the modiolus and osseous spiral lamina to the organ of Corti in the cochlea.

Both the vestibular and cochlear nerves contain among their fibres collections of nerve cells, forming in each nerve a distinct ganglion—the **vestibular ganglion** (g. vestibulare) on the vestibular trunk, and the **spiral ganglion of the cochlea** (g. spirale) on the cochlear trunk.

THE NINTH OR GLOSSO-PHARYNGEAL NERVE.

The glosso-pharyngeal nerve (n. glosso-pharyngeus) (Fig. 517, p. 675) arises from the brain by five or six fine radicles which emerge from the medulla oblongata between the olive and the restiform body, close to the facial nerve above, and in series with the roots of the pneumogastric nerve below (for deep connexions, see p. 517). The rootlets combine to form a nerve which extends outwards to the jugular foramen, through which it passes, along with the pneumogastric and spinal accessory nerves, but enveloped in a separate sheath of dura mater (Fig. 522, p. 678). Reaching the neck, the nerve arches downwards and forwards to the interval between the hyoid bone and the lower jaw. It lies at first between the internal carotid artery and the internal jugular vein, and then between the internal and external carotid arteries, in its course to the side of the pharynx. It sweeps round the stylo-pharyngeus muscle and the stylo-hyoid ligament, and disappears beneath the hyoglossus muscle, to reach its termination in the tongue.

The branches of the nerve may be classified in three series according to their origin—(i.) in the jugular foramen; (ii.) in the neck; (iii.) in relation to the tongue.

In the jugular foramen there are two enlargements upon the trunk of the nerve —the jugular and petrous ganglia. The **jugular ganglion** (g. superius) is small, does not implicate the whole width of the nerve, and may be fused with the petrous ganglion, or even absent altogether. No branches arise from it.

The **petrous ganglion** (g. petrosum) is distinct and constant. It is placed upon the nerve at the lower part of its course through the jugular foramen.

Branches and Communications of the Petrous Ganglion.—The **tympanic branch** (n. tympanicus, Jacobson's nerve) is the most important offset from this ganglion. It passes through a small canal in the bridge of bone between the jugular foramen and the carotid canal to reach the cavity of the tympanum, where it breaks up into branches, to form, along with branches from the carotid plexus of the sympathetic on the internal carotid artery (**small deep petrosal nerve**), the **tympanic plexus** for the supply of the mucous lining of the tympanum, mastoid cells, and Eustachian tube (Fig. 528,

p. 687). The fibres of the tympanic branch of the glosso-pharyngeal nerve become reunited to form, by their union with a small nerve from the geniculate ganglion of the facial nerve, the **small superficial petrosal nerve** in the substance of the temporal bone. This passes forwards through the temporal bone, and eventually joins the otic ganglion.

Besides forming the tympanic branch, the petrous ganglion of the glosso-pharyngeal nerve communicates with three other nerves—(1) with the superior cervical ganglion of the sympathetic; (2) with the auricular branch of the pneumogastric; and (3) sometimes with the ganglion of the root of the pneumogastric.

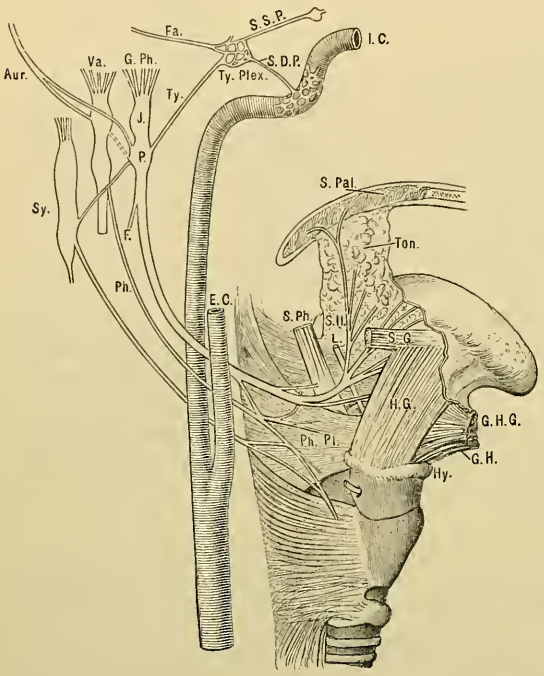


Fig. 531.—Scheme of the Distribution of the Glosso-pharyngeal Nerve.

G.Ph, Glosso-pharyngeal nerve; J, Jugular, and P, Petrous ganglia; Ty, Tympanic branch (Jacobson's nerve); Ty.Plex., Tympanic plexus; Fa, Root from geniculate ganglion of facial nerve; S.S.P, Small superficial petrosal nerve to the otic ganglion; S.D.P, Small deep petrosal nerve; I.C, Internal carotid artery; Va, Pneumogastric nerve; Aur., Auricular branch (Arnold's nerve); Sy., Superior cervical sympathetic ganglion; F, Communicating branch to facial nerve; Ph, Pharyngeal branch of vagus; E.C, External carotid artery; Ph.Pl, Pharyngeal plexus; S.Ph, Stylo-pharyngeus muscle; S.H.L, Stylo-hyoid ligament; H.G, Hyo-glossus; S.G, Stylo-glossus; Ton, Tonsil; S. Pal., Soft palate; G.H.G, Genio-hyoglossus; G.H, Genio-hyoid; Hy, Hyoid bone.

In the neck the glosso-pharyngeal nerve gives off two branches. (1) As it crosses over the **stylo-pharyngeus muscle** it supplies the nerve to that muscle, which sends fibres through it to reach the mucous membrane of the pharynx. (2) The **pharyngeal branches** of the nerve supply the mucous membrane of the pharynx directly after piercing the superior constrictor muscle, and indirectly after joining, along with the pharyngeal offsets from the pneumogastric and the superior cervical ganglion of the sympathetic, in the formation of the **pharyngeal plexus.**

The **terminal branches** of the nerve supply the mucous membrane of the tongue and adjacent parts. A **tonsillitic branch** forms a plexus (circulus tonsillaris) to supply the mucous membrane covering the tonsil, the adjacent part of the soft palate, and the pillars of the fauces. **Lingual branches** supply the mucous membrane of the dorsal third and lateral half of the tongue, extending backwards to the glosso-epiglottidean folds and the front of the epiglottis.

The Tenth or Pneumogastric Nerve.

The pneumogastric or vagus nerve (n. vagus) arises from the brain by numerous radicles attached to the front of the restiform body of the medulla oblongata, in series with the glosso-pharyngeal nerve above and the spinal accessory nerve below it (for deep connexions, see p. 517). Uniting to form a single trunk, the roots of the nerve pass outwards to the jugular foramen, through which they emerge into the neck.

In the jugular foramen the nerve occupies the same sheath of dura mater as the spinal accessory nerve, and is placed behind the glosso-pharyngeal nerve. Two ganglia are present on the trunk in this situation. The higher and smaller is the **ganglion of the root** (g. jugulare); the lower and larger is the **ganglion of the trunk** of the nerve (g. nodosum).

In the neck the pneumogastric nerve pursues a vertical course in front of the spinal column. It occupies the carotid sheath, lying between and behind the internal and common carotid arteries and the internal jugular vein. It enters the

thorax behind the large veins: *on the right side,* after crossing over the subclavian artery; *on the left side,* in the interval between the left common carotid and subclavian arteries.

In the thorax the nerves occupy the superior and posterior mediastinal spaces, and their relations are different on the two sides. (*a*) *In the superior mediastinum* the *right nerve* continues its course alongside the innominate artery and the trachea, and behind the right innominate vein and superior vena cava, to the back of the root of the lung. The *left nerve* courses downwards between the left common carotid and subclavian arteries, and behind the left innominate vein and the phrenic nerve. It passes over the aortic arch, and then proceeds to the back of the root of the left lung. (*b*) *In the posterior mediastinum* the pneumogastric nerves are concerned in the formation of two great plexuses—the pulmonary and the œsophageal. Behind the root of each lung the nerve breaks up to form the large **posterior pulmonary plexus,** from the lower end of which two nerves emerge on each side. These nerves on the right side pass obliquely over the vena azygos major; on the left side they cross the thoracic aorta. Both series reach the œsophagus, and divide into small anastomosing branches which form the **œsophageal plexus.** At the œsophageal opening of the diaphragm the two nerves become separated from the plexus, and entering the abdomen—the left nerve in front of the œsophagus, the right nerve behind it—they terminate by supplying the stomach and other abdominal organs.

The communications and branches of the pneumogastric nerve may be described as (i.) ganglionic, (ii.) cervical, (iii.) thoracic, and (iv.) abdominal (Fig. 532).

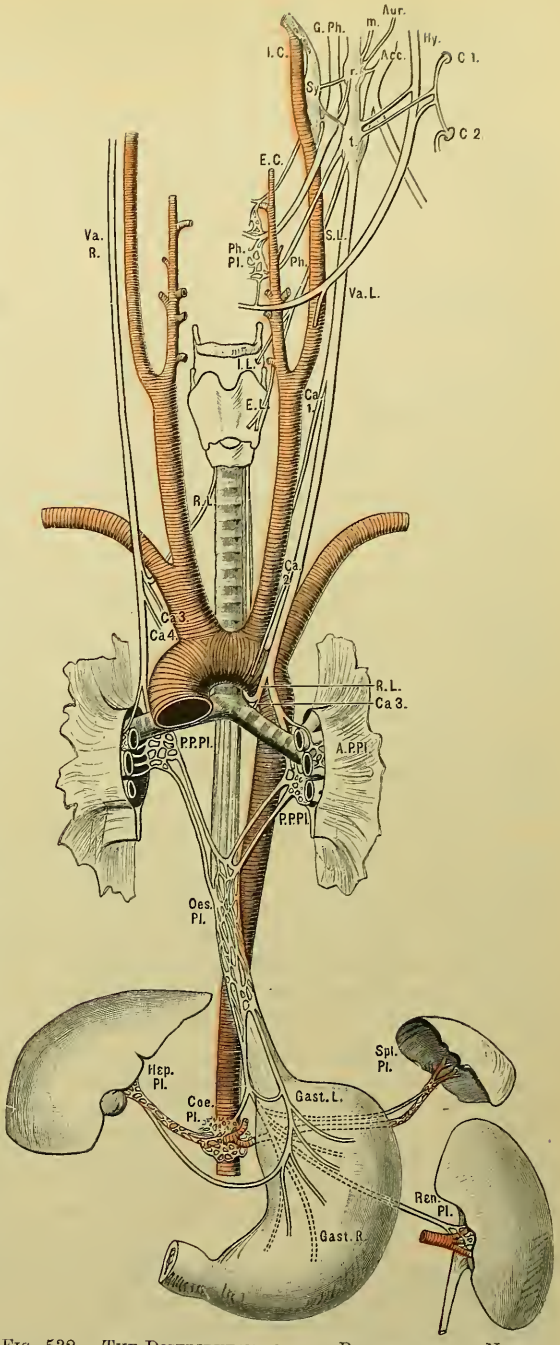


FIG. 532.—THE DISTRIBUTION OF THE PNEUMOGASTRIC NERVE.

Var.R, Va.L, Right and left vagi; r, Ganglion of the root and connexions with Sy, Sympathetic, superior cervical ganglion; G.Ph, Glosso-pharyngeal; Acc, Spinal accessory nerve; m, Meningeal branch; Aur, Auricular branch; t, Ganglion of the trunk and connexions with Hy, Hypoglossal nerve; C1, C2, Loop between the first two cervical nerves; Sy, Sympathetic; Acc, Spinal accessory nerve; Ph, Pharyngeal branch; Ph.Pl, Pharyngeal plexus; S.L, Superior laryngeal nerve; I.L, Internal laryngeal branch; E.L, External laryngeal branch; I.C, Internal, and E.C, External carotid arteries; Ca1, Superior cervical cardiac branch; Ca2, Inferior cervical cardiac branch; R.L, Recurrent laryngeal nerve; Ca3, Cardiac branches from recurrent laryngeal nerves; Ca4, Thoracic cardiac branch (right vagus); A.P.Pl, Anterior, and P.P.Pl, Posterior pulmonary plexuses; Oes.Pl, Œsophageal plexus; Gast.R, and Gast.L, Gastric branches of vagus (right and left); Coe.Pl, Cœliac plexus; Hep.Pl, Hepatic plexus; Spl.Pl, Splenic plexus; Ren.Pl, Renal plexus.

The **ganglion of the root** (g. jugulare) is small and spherical. It occupies the jugular foramen, and gives off two branches—meningeal and auricular.

The **meningeal branch** passes backwards to supply the dura mater of the posterior fossa of the base of the skull.

The **auricular branch** (Arnold's nerve) ascends to the ear in a fissure between the jugular and stylo-mastoid foramina. It receives near its origin a twig from the tympanic branch of the glosso-pharyngeal nerve, and usually communicates with the facial nerve by a branch arising from the latter in the aqueduct of Fallopius. The nerve is distributed to the back of the pinna and the external auditory meatus, and communicates superficially with the posterior auricular nerve.

Communications.—Besides supplying the meningeal and auricular branches, the ganglion of the root of the pneumogastric nerve receives communications from (1) the superior cervical ganglion of the sympathetic; (2) the spinal accessory nerve; and (3) the petrous ganglion of the glosso-pharyngeal nerve (sometimes).

The **ganglion of the trunk** of the nerve (g. nodosum), placed immediately below the preceding, is large and fusiform. Like the previous ganglion, it supplies two branches—the pharyngeal and superior laryngeal nerves.

The **pharyngeal branch** receives its fibres (through the ganglion) from the spinal accessory nerve. It passes obliquely downwards and inwards to the pharynx between the internal and external carotid arteries, and combines with the pharyngeal nerves from the glosso-pharyngeal and superior cervical ganglion of the sympathetic to form the **pharyngeal plexus**. From this plexus the muscles of the pharynx and soft palate (except the stylo-pharyngeus and tensor palati) are supplied. The **lingual branch** is a small nerve which separates itself from the plexus and joins the hypoglossal nerve in the anterior triangle of the neck.

The **superior laryngeal nerve** (n. laryngeus superior) passes obliquely downwards and inwards, behind the external and internal carotid arteries, towards the thyroid cartilage. It divides in its course into two unequal parts—a larger internal and a smaller external laryngeal nerve.

The **internal laryngeal nerve** (ramus internus) passes inwards into the larynx between the middle and inferior constrictor muscles of the pharynx and through the thyro-hyoid membrane. It supplies the mucous membrane of the larynx, reaching upwards to the epiglottis and base of the tongue, and forms communications beneath the ala of the thyroid cartilage with the branches of the inferior laryngeal nerve.

The **external laryngeal nerve** (ramus externus) passes downwards upon the inferior constrictor muscle of the pharynx. It supplies branches to that muscle, and ends in the crico-thyroid muscle.

Communications.—Besides supplying these pharyngeal and laryngeal nerves, the ganglion of the trunk of the pneumogastric has the following communications with other nerves: (1) with the superior cervical ganglion of the sympathetic; (2) with the hypoglossal; (3) with the loop between the first and second cervical nerves; and (4) with the accessory part of the spinal accessory nerve. This part of the nerve applies itself to the ganglion, and thereby supplies to the vagus nerve the inhibitory fibres for the heart, as well as the motor fibres for the pharynx, œsophagus, stomach and intestines, larynx and respiratory organs.

Branches of the Pneumogastric in the Neck.—In the neck the pneumogastric nerve supplies cardiac branches and (on the right side) the inferior or recurrent laryngeal nerve (Fig. 532).

The **cardiac branches** are **superior** and **inferior**. *On the right side* both cardiac branches pass downwards into the thorax behind the subclavian artery, and proceed alongside the trachea to join the deep cardiac plexus. *On the left side* the two nerves separate on reaching the thorax. The *superior nerve* passes deeply alongside the trachea to join the deep cardiac plexus. The *inferior nerve* accompanies the pneumogastric nerve over the aortic arch, along with the superior cervical cardiac branch of the sympathetic, to end in the superficial cardiac plexus.

The **right inferior laryngeal nerve** arises at the root of the neck, as the pneumogastric nerve crosses over the first part of the subclavian artery. It hooks round the artery, and passes obliquely upwards and inwards behind the subclavian,

the common carotid, and the inferior thyroid artery and the thyroid body. It finally disappears beneath the lower border of the inferior constrictor muscle, and ends in supplying the muscles of the larynx. In its course it gives off the following branches:—

(1) **Cardiac branches** arise as the nerve winds round the subclavian artery, and course downwards alongside the trachea to end in the deep cardiac plexus.

(2) **Communicating branches** to the inferior cervical ganglion of the sympathetic arise from the nerve behind the subclavian artery.

(3) **Muscular branches** supply the trachea, œsophagus, and the inferior constrictor of the pharynx.

(4) **Terminal branches** supply the muscles of the larynx (except the crico-thyroid) and communicate beneath the ala of the thyroid cartilage with branches of the internal laryngeal nerve.

Branches of the Vagus in the Thorax.—In the thorax the pneumogastric nerve forms the great pulmonary and œsophageal plexuses. The right nerve, in addition, furnishes cardiac branches; and the left nerve gives off the inferior or recurrent laryngeal nerve.

The **left inferior laryngeal nerve** differs from the nerve of the right side only in its point of origin and in the early part of its course. It springs from the pneumogastric nerve as it crosses the aortic arch, and, after hooking round the arch external to the *ligamentum arteriosum*, it passes upwards in the superior mediastinum in the interval between the trachea and œsophagus to the neck. In the neck its course and relations are similar to those of the nerve of the right side. The branches of the nerve are the same as those of the right nerve. The **cardiac branches** are larger, and, arising below the aortic arch, proceed to the deep cardiac plexus.

Cardiac branches from the right pneumogastric nerve arise in the superior mediastinum, and pass downwards alongside the trachea to join the deep cardiac plexus. On the *right side* thoracic cardiac branches are thus supplied from both the trunk of the nerve and its recurrent branch; *on the left side* the cardiac branches in the thorax arise solely from the recurrent branch.

Abdominal Branches.—After the formation of the œsophageal plexus the two pneumogastric nerves resume their course, and passing along with the gullet through the diaphragm, terminate by supplying the stomach. The *right nerve* enters the abdominal cavity behind the gullet, and is distributed to the posterior surface of the stomach. It sends communicating offsets to the cœliac, splenic, and renal plexuses. The *left nerve* applies itself to the anterior surface and lesser curvature of the stomach, to which it is distributed. It sends communicating offsets along the lesser curvature of the stomach to the right pneumogastric, and between the layers of the small omentum to the hepatic plexus.

The Thoracic Plexuses.

Cardiac Plexuses.—The cardiac branches of the pneumogastric nerve (both cervical and thoracic) combine with the cervical cardiac branches of the sympathetic to form the superficial and deep cardiac plexuses.

The **superficial cardiac plexus** is placed in the hollow of the aortic arch, superficial to the pericardium. It contains a small ganglion (**ganglion of Wrisberg**), and is joined by two small nerves—(1) the cardiac branch from the superior cervical ganglion of the sympathetic, and (2) the inferior cervical cardiac branch of the pneumogastric—both of the left side—which reach it after passing over the arch of the aorta.

Branches and Communications.—From the plexus branches of communication pass (1) to the left half of the **deep cardiac plexus**, between the aortic arch and the bifurcation of the pulmonary artery; (2) to the left **anterior pulmonary plexus** along the left branch of the pulmonary artery; (3) the branches of distribution to the heart extend along the pulmonary artery to join the **anterior or right coronary plexus**, which supplies the substance of the heart in the course of the right coronary artery.

The **deep cardiac plexus** is much the larger. It is placed behind the arch of the aorta, on the sides of the trachea, just above its bifurcation. It consists of two lateral parts, joined together by numerous communications around the termination of the trachea. The two portions of the plexus are different in their constitution and distribution. The *right half* of the plexus is joined by both the cervical and thoracic branches of the right pneumogastric and by the branches of the right inferior laryngeal nerve, as well as by branches from the superior, middle, and inferior cervical ganglia of the sympathetic. The *left half* of the plexus is joined by the superior cervical cardiac branch of the left pneumogastric, by branches from the left inferior laryngeal nerve, and by branches from the middle and inferior cervical ganglia of the left sympathetic; it also receives a contribution from the superficial cardiac plexus.

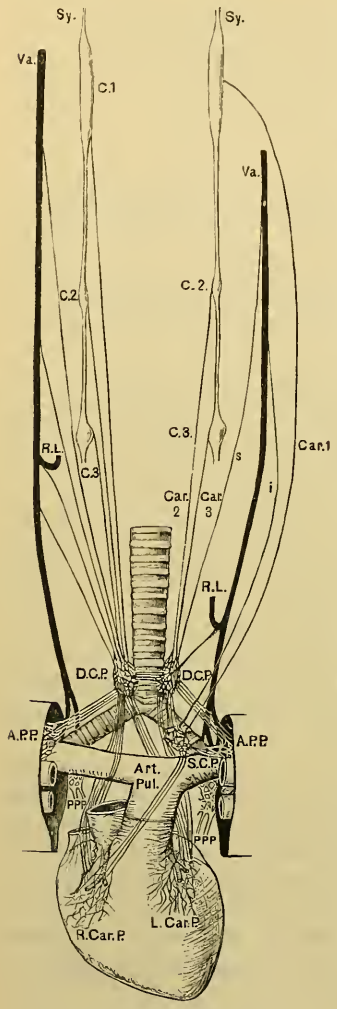


FIG. 533.—THE CONSTITUTION OF THE CARDIAC PLEXUSES.

Sy, Cervical sympathetic cord; C.1, Superior, C.2, Middle, and C.3, Inferior cervical ganglia; Car. 1, Superior, Car. 2, Middle, and Car. 3, Inferior cervical cardiac sympathetic branches; Va, Pneumogastric nerve; R.L, Recurrent laryngeal nerve; s, Superior, and i, Inferior cervical cardiac branches of vagus; D.C.P, Deep cardiac plexus; S.C.P, Superficial cardiac plexus; A.P.P, Anterior pulmonary plexus; P.P.P, Posterior pulmonary plexus; R.Car.P, Right, and L.Car.P, Left coronary plexuses; Art.Pul, Pulmonary artery.

The deep cardiac plexus is distributed to the heart and lungs. The *right half* of the plexus for the most part constitutes the **anterior** or **right coronary plexus**, reaching the heart alongside the ascending aorta, and is distributed to the heart substance in the course of the right coronary artery. It is reinforced by fibres from the superficial cardiac plexus, which reach the heart along the pulmonary artery. Fibres from the right half of the deep cardiac plexus pass also to join the **posterior** or **left coronary plexus**, and others extend outwards to join the **anterior pulmonary plexus** of the right side.

The *left half* of the deep cardiac plexus, reinforced by fibres from the superficial cardiac plexus, is distributed to the heart in the form of the **left** or **posterior coronary plexus**, which is joined by a few fibres behind the pulmonary artery from the right half of the plexus, and supplies the heart substance in the course of the left coronary artery. The left half of the plexus contributes also to the **left anterior pulmonary plexus** by fibres which extend outwards to the root of the lung along the left branch of the pulmonary artery.

Pulmonary Plexuses.—As already stated, the pneumogastric nerve on each side, on reaching the back of the root of the lung, breaks up into numerous plexiform branches for the formation of the posterior pulmonary plexus. From each nerve a few fibres pass to the front of the root of the lung, above its upper border, to form the much smaller anterior pulmonary plexus.

The **anterior pulmonary plexus** on each side is joined by a few fibres from the corresponding part of the deep cardiac plexus, and on the left side from the superficial cardiac plexus as well. It surrounds and supplies the constituents of the root of the lung anteriorly.

The **posterior pulmonary plexus**, placed behind the root of the lung, is formed by the greater part of the pneumogastric nerve, reinforced by fine branches from the second, third, and fourth thoracic ganglia of the sympathetic. Numerous branches proceed from it in a plexiform manner along the bronchi and vessels into the substance of the lung.

Œsophageal Plexus (plexus gulæ). — The œsophagus in the thorax is supplied by the pneumogastric nerve both in the superior and posterior mediastinum. *In the superior mediastinum* it receives branches from the pneumogastric nerve on the right side, and from its recurrent laryngeal branch on the left side.

In the posterior mediastinum it is surrounded by the œsophageal plexus, formed from the trunks of the pneumogastric nerves emerging from the posterior pulmonary plexus, which form a large plexus surrounding the gullet. This part of the œsophagus also receives fibres from the great splanchnic nerve and ganglion. From the œsophageal plexus branches supply the muscular wall and mucous membrane of the œsophagus.

Pericardiac branches are also supplied from the plexus to the posterior surface of the pericardium.

The Eleventh or Spinal Accessory Nerve.

The spinal accessory nerve (n. accessorius) consists of two essentially separate parts, different both in origin and in distribution. One portion is **accessory to the vagus nerve**, and arises, in series with the fibres of that nerve, from the side of the medulla oblongata. The other, **spinal portion**, arises from the lateral aspect of the spinal cord, between the ventral and dorsal roots of the spinal nerves, its origin extending from the level of the accessory portion as low as the origin of the sixth cervical nerve (for the deep origin, see p. 516). Successively joining together, the rootlets form a trunk which ascends in the subdural space of the spinal cord, behind the ligamentum denticulatum, to the foramen magnum. There the

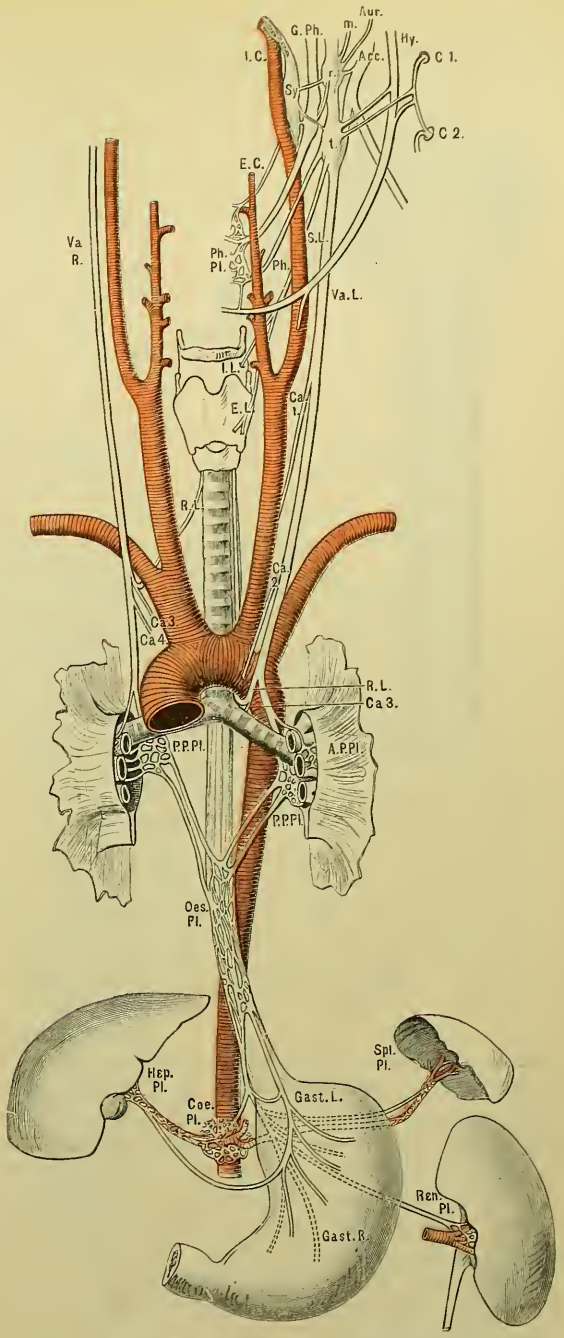


Fig. 534.—The Distribution of the Pneumogastric Nerve.

Va.R, Va.L, Right and left vagi; r, Ganglion of the root and connexions with Sy, Sympathetic, superior cervical ganglion; G.Ph, Glosso-pharyngeal; Acc, Spinal accessory nerve; m, Meningeal branch; Aur, Auricular branch; t, Ganglion of the trunk and connexions with Hy, Hypoglossal nerve; C1, C2, Loop between the first two cervical nerves; Sy, Sympathetic; Acc, Spinal accessory nerve; Ph, Pharyngeal branch; Ph.Pl, Pharyngeal plexus; S.L, Superior laryngeal nerve; I.L, Internal laryngeal branch; E.L, External laryngeal branch; I.C, Internal, and E.C, External carotid arteries; Ca1, Superior cervical cardiac branch; Ca2, Inferior cervical cardiac branch; R.L, Recurrent laryngeal nerve; Ca3, Cardiac branches from recurrent laryngeal nerves; Ca4, Thoracic cardiac branch (right vagus); A.P.Pl, Anterior, and P.P.Pl, Posterior pulmonary plexuses; Oes.Pl, Œsophageal plexus; Gast.R, and Gast.L, Gastric branches of vagus (right and left); Coe.Pl, Coeliac plexus; Hep.Pl, Hepatic plexus; Spl.Pl, Splenic plexus; Ren.Pl, Renal plexus.

accessory and spinal portions unite into a single trunk, which leaves the cranial cavity through the jugular foramen in the same compartment of dura mater as the pneumogastric nerve (Fig. 522, p. 678).

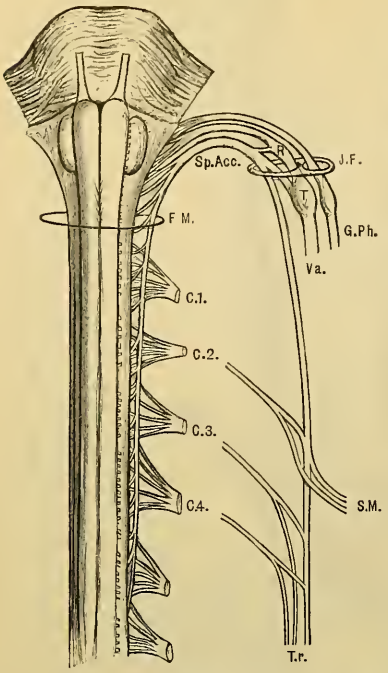


Fig. 535.—Scheme of the Origin, Connexions, and Distribution of the Spinal Accessory Nerve.

Sp.Acc, Spinal accessory nerve; C.1-4, First four cervical nerves (dorsal roots); Va, Pneumogastric nerve; R, Ganglion of the root; T, Ganglion of the trunk; G.Ph, Glosso-pharyngeal nerve; S.M, Nerves to sterno-cleido-mastoid; Tr, Nerves to trapezius; F.M, Foramen magnum; J.F, Jugular foramen.

In the jugular foramen the **accessory portion of the nerve** (after furnishing a small branch to the ganglion of the root of the pneumogastric nerve) applies itself to the ganglion of the trunk, and in part joins the ganglion, in part the trunk of the nerve beyond the ganglion. By means of these connexions the pneumogastric receives viscero-motor and cardio-inhibitory fibres.

The **spinal portion** of the nerve extends into the neck, where at first it lies along with other nerves, in the interval between the internal carotid artery and the internal jugular vein. Passing obliquely downwards and outwards over the vein, it descends beneath the sterno-mastoid muscle, which it supplies as it pierces it on its deep surface. After crossing the posterior triangle the nerve ends by supplying the trapezius muscle on its under surface. The spinal portion of the nerve *communicates* in three situations with nerves from the cervical plexus—(1) in or beneath the sterno-mastoid, with the branch for the muscle derived from the second cervical nerve; (2) in the posterior triangle, with branches from the third and fourth cervical nerves; (3) beneath the trapezius, with the branches for the muscle derived from the third and fourth cervical nerves.

The Twelfth or Hypoglossal Nerve.

The hypoglossal nerve (n. hypoglossus) arises by numerous radicles from the front of the medulla oblongata between the pyramid and the olive (Fig. 517, p. 675) (for deep origin, see p. 515). The root fibres arrange themselves in two bundles which separately pierce the dura mater, and unite in the anterior condyloid foramen, or after emerging from the skull. In the neck the nerve arches downwards and forwards towards the hyoid bone, and then turns inwards among the suprahyoid muscles to the tongue. At first it is placed deeply, along with other cranial nerves, on the outer side of the internal carotid artery; it then curves forwards and downwards over the two carotid arteries lying beneath the digastric and stylohyoid muscles. As it crosses the external carotid artery it hooks round the occipital artery. Above the great cornu of the hyoid bone the nerve conceals the lingual artery; and it then disappears between the mylo-hyoid and hyo-glossus muscles to reach the tongue, in the muscular substance of which it terminates.

Communications.—In its course the hypoglossal nerve has the following communications with other nerves:—Near the base of the skull it is connected by small branches with (1) the superior cervical ganglion of the sympathetic; (2) the ganglion of the trunk of the pneumogastric; (3) by a larger branch, with the loop between the first two cervical nerves; (4) as it crosses the external carotid artery it receives a communication from the pharyngeal plexus (*lingual branch of the vagus*); and (5) beneath the mylo-hyoid muscle, at the anterior border of the hyo-glossus, it forms loops of communication with the lingual branch of the inferior maxillary nerve.

The **branches** of the nerve are:—(1) Recurrent; (2) Descending; (3) Thyro-hyoid; and (4) Lingual.

The **recurrent branch** passes from the nerve near its origin to supply the dura mater of the posterior fossa of the base of the skull. It probably derives its fibres from the communication with the first and second cervical nerves.

The **descending hypoglossal nerve** (n. descendens) is the chief branch given off in the neck. It arises from the hypoglossal nerve as it crosses the internal carotid artery, and descends in the anterior triangle in front of the carotid sheath. It is joined about the middle of the neck by the **descending cervical nerve** (from the second and third cervical nerves). By their union the **hypoglossal loop** (ansa

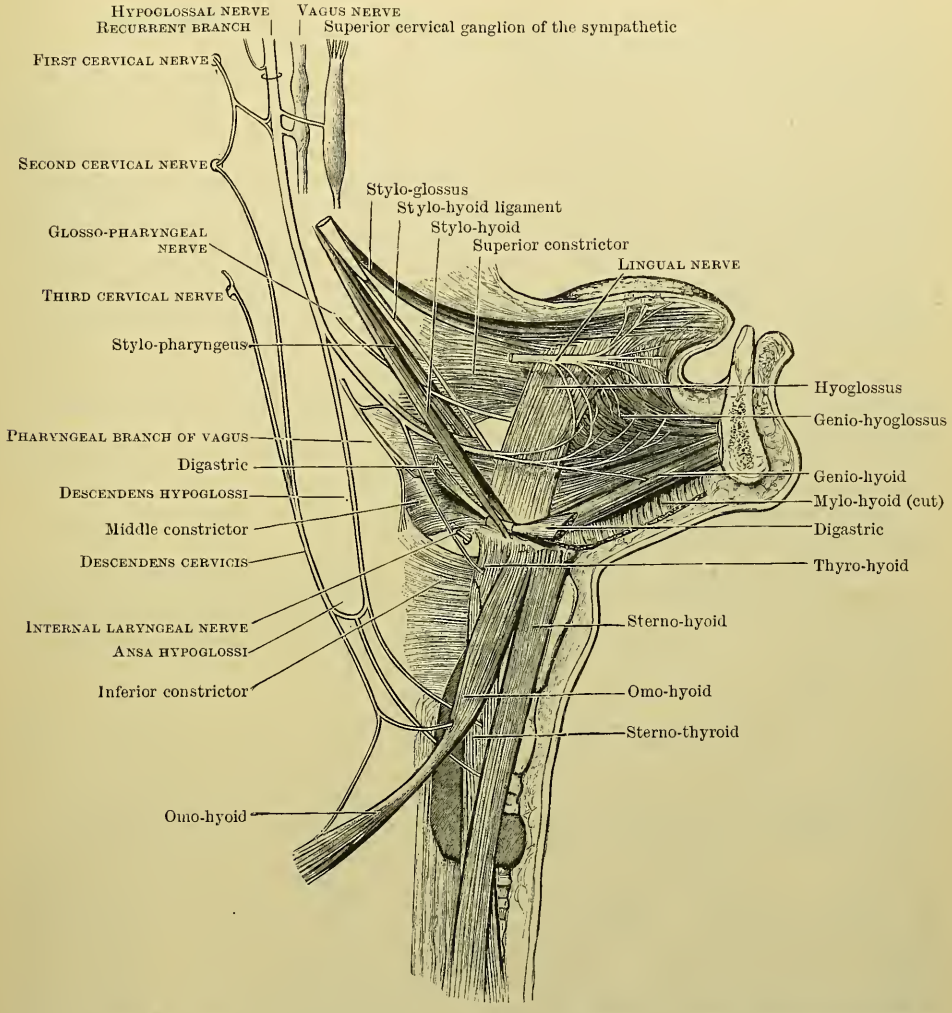


Fig. 536.—The Muscles of the Hyoid Bone and Styloid Process, and the Extrinsic Muscles of the Tongue with their Nerves.

hypoglossi) is formed, from which branches are distributed to the majority of the infra-hyoid muscles—both bellies of the omo-hyoid, the sterno-hyoid, and the sterno-thyroid. The descending hypoglossal nerve derives its fibres from the communication to the hypoglossal nerve from the loop between the first and second cervical nerves; so that the ansa hypoglossi is made up of fibres of the first three cervical nerves.

The **nerve to the thyro-hyoid muscle** is a small branch which arises from the hypoglossal nerve before it passes beneath the mylo-hyoid muscle. It descends behind the great cornu of the hyoid bone to reach the muscle. When traced backwards this nerve is found associated with the loop between the first and second cervical nerves.

The **lingual branches** of the hypoglossal nerve are distributed to the hyo-glossus, genio-hyoid, and genio-hyo-glossus, and to all the intrinsic muscles of the tongue. The nerve to the genio-hyoid is said to be derived from the loop between the first and second cervical nerves. It is not known if these two nerves are implicated in the innervation of the proper muscles of the tongue, but it appears certain that the muscles named—the genio-hyoid, thyro-hyoid, sterno-hyoid, omo-hyoid, and sterno-thyroid—are not supplied by the hypoglossal, but only by cervical nerves, the genio-hyoid by the first two, the other muscles by the first three cervical nerves.

THE DEVELOPMENT OF THE CRANIAL NERVES.

Omitting the first and second nerves, there is an obvious likeness in the development of the several cranial nerves to the formation of the dorsal, afferent or sensory, and the ventral, efferent or motor, roots of the spinal nerves. The **afferent roots** of the cranial nerves arise from collections of cells which bud off from the alar lamina of the brain, homologous with the dorso-lateral part of the spinal cord. These cells give rise to central and peripheral processes, like the similar processes from the dorsal ganglia of the spinal nerves, producing on the one hand the root fibres connected with the brain, and on the other hand the fibres of the nerve proceeding to the periphery. The **efferent roots**, like the ventral roots of the spinal nerves, arise as the peripheral processes of neuroblasts located in the basal lamina of the primitive brain, which is homologous with the ventro-lateral portion of the spinal cord. The different efferent nerves may be separated into two series, according as they arise from the mesial or lateral parts of the basal lamina. The third, fourth, sixth, and twelfth nerves arise from the mesial part of the lamina; the efferent fibres of the fifth, seventh, ninth, tenth, and eleventh nerves arise from the lateral part of the lamina.

The **olfactory nerves** are associated in their development with the formation of the nasal pit and the olfactory bulb.

The **nasal pits** appear in each side of the front of the head at a little later period than the formation of the lens and the auditory vesicle. They become converted into the nasal cavities by the formation of the pre-oral visceral clefts and arches,—fronto-nasal and ethmo-vomerine in the middle line, and lateral ethmoid and maxillary processes at the sides (p. 38).

The **Rhinencephalon** or **olfactory bulb** is a hollow outgrowth from each telencephalon or cerebral hemisphere, which appears in the first month. It grows forwards into relation with the deep surface of the nasal pit. In many animals (as in the horse) the olfactory bulb remains hollow; but in the human subject it loses its lumen and becomes a solid bulb (**olfactory bulb**) connected to the brain by a narrow stalk, the **olfactory tract.**

The **epithelium of the nasal pit** is responsible for the formation of the olfactory nerves. There are two views as to the mode of their development from the epithelial cells. Both views admit the proliferation of the epithelium of the nasal pit so as to produce *neuroblasts.* According to the one view these neuroblasts detach themselves from the epithelial surface, and constitute **an olfactory ganglion** which becomes applied to and incorporated with the olfactory bulb. The cells of the ganglion become bi-polar, and the peripheral axons constitute the *olfactory nerves*, while the central axons (in the second month) proceed backwards to the brain along the olfactory tract. According to the other view (based on Disse's investigations), the proliferating cells of the nasal epithelium remain in the wall of the nasal pit, and become the *olfactory cells* of the nasal cavity, with peripheral processes projecting to the surface of the epithelium. Their central axons become the olfactory nerve fibres which end in the olfactory bulb, forming dendrites associated with the dendritic processes of the nerve-cells of the bulb. The central axons of these latter cells develop into the fibres of the olfactory tract.

The **optic nerve** is developed wholly from the brain. Its formation begins with the outgrowth of the optic vesicle, a paired hollow outgrowth from the ventral surface of the thalamencephalon. The epiblastic invagination of the lens, growing inwards from the surface of the head, causes the collapse of the vesicle and its conversion into the **optic cup**, the narrow tube connecting the vesicle to the brain becoming the **optic stalk.** This stalk becomes solid, and forms the basis of the optic tract, optic commissure, and optic nerve. The optic cup, bilaminar in form, and by its edge clasping the lens, is embedded in mesoblastic tissue, which gives rise to the envelopes of the eyeball, etc. The *outer*

layer of the optic cup produces the layer of hexagonal pigment cells of the retina. The cells of the *inner layer* produce the tissue of the retina proper. They form neuroblasts with peripheral and central processes. The peripheral processes are converted into retinal nerve tissues; the central processes extend backwards along the optic stalk, and give rise to the fibrous structure of the optic nerve, optic commissure, and optic tract. Spongioblasts in the inner lamina of the optic cup produce the sustentacular tissue of the retina (Müller's fibres). The mesoblastic tissue surrounding the optic cup and lens gives rise to the rest of the structure of the eyeball, the formation of which is described in the section which deals with the organs of sense.

The **oculo-motor nerve** arises, like the ventral root of a spinal nerve, from a group of neuroblasts in the mesial part of the basal lamina of the mid-brain. The peripheral fibres extend forwards, to end around the optic cup in the mesoblastic tissue, from which the eye muscles are derived. Numerous cells are carried along with the cell processes in their course, and these have been described as being concerned in the formation of the ciliary ganglion.

The **trochlear nerve** also arises from a group of neuroblasts occupying the mesial part of the basal lamina of the mid-brain, close to its junction with the hind-brain. The peripheral processes do not emerge directly from the brain, but extend dorsally from their origin along the side of the brain to its dorsal aspect, where they appear, after decussating with the fibres of the opposite nerve, just behind the quadrigeminal lamina.

The **trigeminal nerve** is developed by means of a large dorsal and a small ventral root. Their origin to a large extent resembles the mode of formation of the roots of a spinal nerve.

The large **dorsal (afferent) root** is formed by means of a cellular bud from the alar lamina of the hind-brain. This bud separates from the brain, and forms the Gasserian ganglion. Its cells becoming bipolar, like the cells of a spinal ganglion, are secondarily connected with the brain by means of their central processes; while the peripheral processes, separating into three groups, proceed along the fronto-nasal and maxillary processes, and along the mandibular arch, to form the three main divisions of the nerve. Numerous cells accompany each main division in its course from the ganglion, and form eventually the subordinate ganglia—the *ciliary* on the ophthalmic nerve, the *spheno-palatine* on the superior maxillary nerve, and the *otic ganglion* on the inferior maxillary nerve.

The small **ventral (efferent) root** of the trigeminal nerve, like the motor ventral root of a spinal nerve, is later in its appearance than the sensory root. It arises as the peripheral fibres of a group of neuroblasts occupying the lateral part of the basal lamina of the hind-brain, which proceed directly to the surface to join the inferior maxillary division of the nerve.

The **abducent nerve** resembles in its mode of development the oculo-motor and trochlear nerves with which in its origin it is in series. It is formed by the peripheral processes of a group of neuroblasts in the mesial part of the basal lamina in the upper part of the hind-brain. These processes pierce the part of the brain in which, at a later stage, the fibres of the pyramid are developed. They then proceed to the mesoblastic tissue round the optic cup, which is destined to form the eye muscles.

The **facial nerve** has developmentally a double origin. (1) In connexion with the formation of the auditory nerve a group of cells becomes separated from the alar lamina of the hind-brain opposite the auditory vesicle. This group becomes separated into three parts, of which the middle portion is the rudiment of the **geniculate ganglion** (or afferent root). (2) The **efferent root** of the nerve arises from a group of neuroblasts in the lateral part of the basal lamina of the hind-brain, in series with efferent fibres of the vago-glosso-pharyngeal nerves; after a tortuous course within the brain its fibres emerge beneath the above-mentioned cellular mass, opposite the auditory vesicle. They are joined by the ganglionic root, and in their course round the auditory vesicle become embedded in the auditory capsule (aqueduct of Fallopius). The chorda tympani nerve appears early as a branch of the facial nerve. It is probable that the pars intermedia, the geniculate ganglion, and the chorda tympani nerve together represent the **dorsal afferent element** in the constitution of this nerve.

The **auditory nerve** arises as a cellular bud from the alar lamina of the hind-brain, dorsal to the efferent portion of the facial nerve and opposite to the auditory vesicle, and in close association with the latter.

Becoming separated from the brain, the cellular mass separates into three portions, of which the middle part is associated with the facial nerve and pars intermedia (as the geniculate ganglion), while the mesial and lateral parts are converted into the mesial (vestibular) and lateral (cochlear) ganglia and roots of the auditory nerve. The cells

becoming bipolar, their central processes are secondarily connected with the brain on the dorsal (lateral) aspect of the facial nerve; the peripheral processes proceed to the auditory vesicle, to which they are distributed as the vestibular and cochlear nerves. Numerous cells are carried along with the nerve trunks into relation with the auditory capsule, and constitute the vestibular and cochlear ganglia.

The **glosso-pharyngeal** and **pneumogastric nerves** are developed from the side of the hind-brain, both in the same way, and each by two roots. A collection of cells separates itself from the alar lamina of the hind-brain behind the auditory vesicle to form the **ganglionic afferent root.** The ganglion of the pneumogastric is much larger than that of the glosso-pharyngeal. Each ganglion becomes divided into two parts, a proximal and a distal portion, connected together by a commissural band of fibres. The proximal ganglion (jugular ganglion of the glosso-pharyngeal; ganglion of the root of the pneumogastric) is secondarily connected by centripetal fibres to the hind-brain. From the distal ganglion (petrous ganglion of the glosso-pharyngeal; ganglion of the trunk of the pneumogastric) peripheral fibres grow outwards to form the nerve trunk.

Each nerve is also provided with a small **efferent root,** consisting of nerve fibres, arising from a collection of neuroblasts in the lateral part of the basal lamina of the hind-

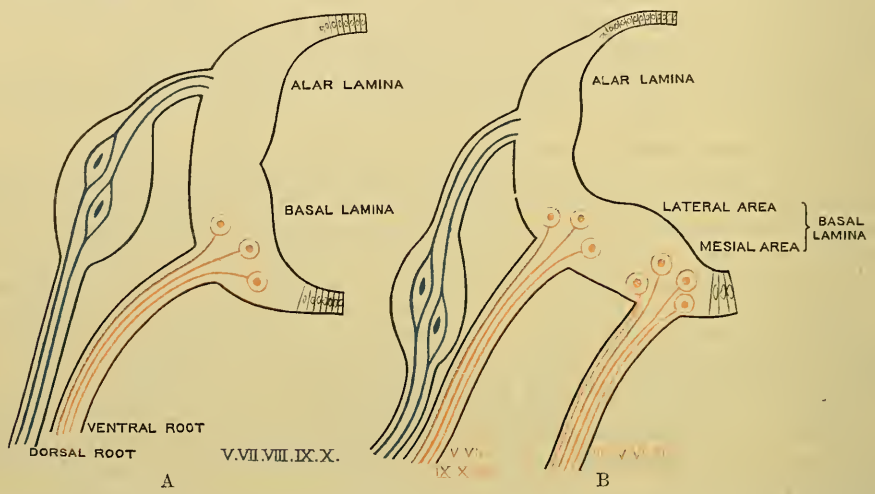


FIG. 537.—COMPARISON OF ORIGINS OF NERVE ROOTS FROM SPINAL CORD AND HIND-BRAIN (after His).
A. Spinal cord; B. Hind-brain.

brain, and emerging beneath the ganglionic root at the junction of the alar and basal laminæ (in series with the fibres of the efferent root of the facial nerve above and of the spinal accessory nerve below).

The **spinal accessory nerve** arises in two parts—one medullary, the other spinal. The **medullary** (accessory) portion develops as the processes of a series of neuroblasts in the lateral portion of the basal lamina of the hind-brain, which emerge in series with the efferent roots of the glosso-pharyngeal and pneumogastric nerves. The **spinal portion** arises as the processes of a group of neuroblasts in the ventral part of the medullary tube (anterior cornu), which, turning outwards, emerge as a series of roots on the lateral aspect of the spinal cord.

The **hypoglossal nerve** is developed, not in series with the nerves above mentioned, but like the third, fourth, and sixth nerves, from the mesial part of the basal lamina of the hind-brain, in the space between the glosso-pharyngeal and other nerves above, and the first cervical nerve below. It is formed as a series of peripheral processes from a collection of neuroblasts occupying the hind-brain. **Froriep's ganglion** is a transitory collection of nerve cells developed from the alar lamina of the hind-brain on the dorsal aspect of the nerve, and represents in a rudimentary condition its dorsal ganglionic root. It gives off no branches and soon disappears.

THE MORPHOLOGY OF THE CRANIAL NERVES.

The head and face, possibly the oldest, and from every point of view the most fundamental and important portion of the bodily fabric, present in some respects a more conservative type of structure, and in other aspects have been subject to more profound alterations than other parts

of the body. Segmentation is characteristic of the trunk, pervading bones, muscles, vessels, and nerves. An absence of true segmentation is characteristic of the head region—omitting for the moment the cranial nerves. The head is characterised by the possession of an unsegmented tubular nervous system, enclosed in a bony capsule not obviously segmental, with which the capsules of the sense-organs become united. The pre-oral and post-oral visceral arches and clefts are not truly segmental like the costal arches of the trunk. The branchial clefts are said to be inter-segmental; and their muscles (associated with the myoblast surrounding the developing heart) are described as visceral, and not myotomic, so that the branchial vessels and nerves (similarly) are not to be regarded as comparable to the segmental vessels and nerves of the trunk. The truly segmental structures present are certain persistent myotomes or muscle plates, which give rise to muscles innervated by the third, fourth, sixth, and twelfth cranial nerves.

Another difficulty in the morphology of the head arises in the absence of body cavity, and the consequent difficulty of differentiating the somatic and splanchnic mesoblast, and the somatic and splanchnic distribution of a given nerve.

Under these circumstances there is little help to be derived from head structures other than the nerves themselves in seeking a solution of the question of the morphological relations of the cranial nerves. The spinal nerves are, generally speaking, all alike. The cranial nerves, on the other hand, are all different. Scarcely any two nerves are alike; and no single cranial nerve possesses in itself all the characteristic features of a spinal nerve. As seen in relation to their development, the cranial nervous system possesses a series of dorsal ganglia, comparable in position and development to the spinal ganglia from which afferent nerves arise; and the efferent roots are developed in the same way, and occupy somewhat the same position as the ventral roots of the spinal nerves. But there is no single complete segmental nerve in the head. The very essence of the architecture of the head is a want of segmentation; and this character is shared by the cranial nerves. In addition it must be borne in mind that, in relation to the mammalian head, there are organs which have no homologues in the trunk, and on whose existence the arrangement of the cranial nerves depends—*e.g.* sense-organs and gill-arches.

Among the cranial nerves there are several which possess a resemblance to one or other of the elements of a typical spinal nerve. In the neck the origin of the fibres of the spinal accessory nerve is from the side of the spinal cord, and it is in series with the motor roots of the vago-glosso-pharyngeal, facial, and fifth nerves. His (as shown in the account of the development of the nerves) has described the neuroblastic origin of the motor roots of these nerves from the lateral part of the basal lamina of the primitive brain. They thus form a series apart—lateral motor roots—separable from the series of motor roots originating from the mesial part of the basal lamina, comprising those of the third, fourth, sixth, and twelfth nerves; the latter nerve roots being comparable to and in series with the ventral roots of the spinal nerves. The lateral motor roots are not represented in the spinal series except in the neck. It is questionable if there is any fundamental distinction between the lateral and ventral motor roots of the cranial nerves. The spinal accessory fibres, for example, when traced into the spinal cord, have an origin from the anterior cornu of the cord, and only differ from the motor or ventral root fibres of a spinal nerve in their different course to the surface. The ganglia in association with the cranial nerves are comparable to the spinal ganglia. The fifth nerve, with the Gasserian ganglion, the ganglion of the facial, the ganglia of the auditory, of the glosso-pharyngeal and the vagus, and the transitory (Froriep's) ganglion of the hypoglossal nerves, arise from the brain in a comparable position, and in the same way as the spinal ganglia. But another series of structures —the sense organs of the lateral line, and the so-called "epibranchial" organs which are highly developed in lower vertebrates (*e.g.* elasmobranchs), and which appear transitorily only, or are absent altogether in mammalian development, may possibly have a share in the formation of certain of these ganglia or parts of them (*e.g.* ciliary ganglion, geniculate ganglion, ganglia of the auditory nerve, petrosal ganglion of the glosso-pharyngeal, and the ganglion of the trunk of the vagus).

Certain of the cranial nerves are apparently distinctly **segmental**, supplying muscles derived from the persisting myotomes of the head. The **first three myotomes** are said to give rise to the muscles of the eyeball. The *first* produces the superior rectus, inferior rectus, internal rectus, and inferior oblique muscles, and its segmental nerve is the **oculo-motor**. The *second myotome* is said to produce the superior oblique muscle, and its segmental nerve is the **trochlear**. The *third myotome* is said to produce the external rectus muscle, and its segmental nerve is the **abducent**. It has been asserted that the tongue muscles are derived from the **last three or four cephalic and first cervical myotomes**, and that the **hypoglossal nerve** is the segmental nerve for these myotomes, comprising the motor elements of several (four or five) segmental nerves. The intervening myotomes between the first three and this occipital series disappearing, the corresponding elements of segmental nerves are supposed to be absent also (Fig. 538).

Certain of the cranial nerves are essentially related to the structures derived from and associated with the pre-oral and post-oral **visceral clefts and arches** (Fig. 539). The **trigeminal nerve** is essentially the nerve of the **mandibular arch**. By its efferent root it supplies the muscles of that arch. By its afferent root and branches it is related to (1) the fronto-nasal process (ophthalmic division and ciliary ganglion); (2) the maxillary arch (superior maxillary nerve); and (3) the mandibular arch (inferior maxillary nerve). The mandibular is at first the main nerve; and the maxillary division is sometimes regarded as a subordinate branch (pre-branchial, pre-trematic) for the supply of the anterior margin of the cleft (mouth), with which the nerve is in relation. The ophthalmic nerve is sometimes regarded as a morphologically separate nerve. The nerves to these arches have been compared to the anterior primary divisions of spinal

nerves, the branches which they supply to the forehead and temple (frontal, orbital, and auriculo-temporal) representing the posterior primary divisions. The ganglia on each division of the nerve are formed as extensions from the Gasserian ganglion.

The **facial nerve** is essentially the nerve of the **second (hyoid) arch**, and the cleft in front of that arch (spiracular cleft, Eustachian tube). Its motor root supplies the muscles of that arch (stapedius, stylo-hyoid, and digastric), and the epicranial and facial muscles and platysma myoides, which are developments from the hyoid arch (Rabl). The **chorda tympani nerve** is regarded as the subordinate (præ-branchial, præ-trematic) branch to supply the anterior margin of the first post-oral cleft. It is possible that the geniculate ganglion, with the pars intermedia and the chorda tympani, may, in part at least, represent the ganglionic and afferent element of the nerve. Or the geniculate ganglion, and the nerves in relation to it, may be associated with an "epibranchial" sense-organ.

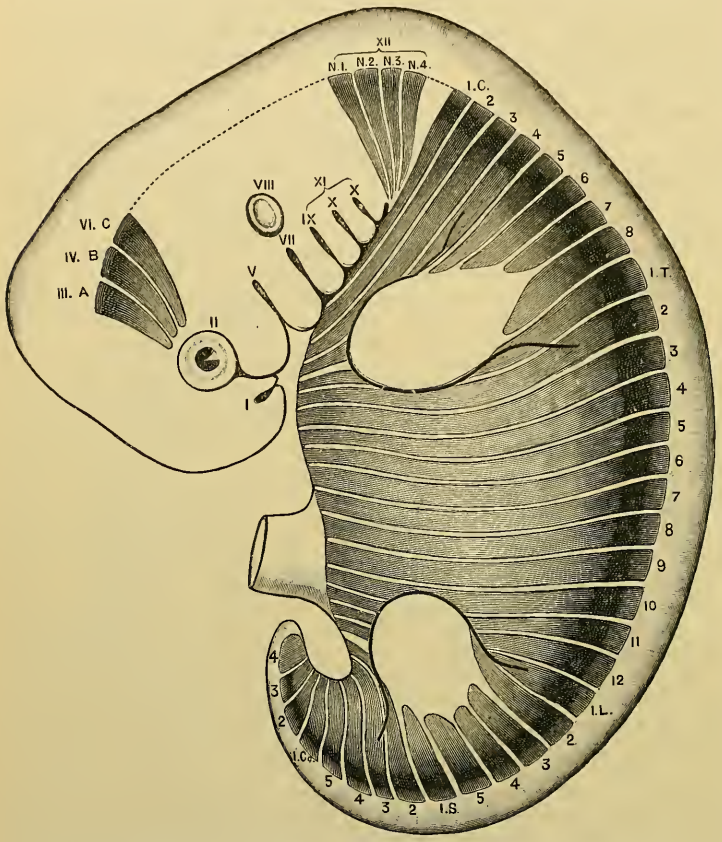


Fig. 538.—Scheme to illustrate the Disposition of the Myotomes in the Embryo in Relation to the Head, Trunk, and Limbs.

A, B, C, First three cephalic myotomes; N, 1, 2, 3, 4, Last persisting cephalic myotomes; C, T, L, S, Co, The myotomes of the cervical, thoracic, lumbar, sacral, and caudal regions; I., II., III., IV., V., VI., VII., VIII., IX., X., XI., XII., refer to the cranial nerves, and the structures with which they may be embryologically associated.

The **auditory nerve**, on the other hand, may be either the sensory element of the branchial nerve, associated with the **hyoid arch** and first post-oral cleft, or it may represent the nerve or nerves belonging to ancestral sense-organs of the lateral line.

The **glosso-pharyngeal** is the branchial nerve of the **third post-oral** (*thyro-hyoid*) **arch** and the cleft in front. Its efferent fibres supply the muscle of this arch, —the stylo-pharyngeus. The superior constrictor of the pharynx is also assigned to this arch; the middle and inferior muscles to the fourth (first branchial) arch. The afferent portion of the nerve is possibly composed of two separate parts; the petrous ganglion being associated with an epibranchial or lateral line sense-organ, and the rest of the nerve forming the afferent fibres for the gill-cleft and arch. The lingual branches are regarded as the main stem (post-trematic), the pharyngeal branches as subordinate branches; the tympanic branch being the præ-branchial or præ-trematic branch for the anterior margin of the third gill-cleft.

The **pneumogastric nerve** is generally regarded as representing the fusion of all the branchial nerves behind the glosso-pharyngeal. Its efferent fibres are in series with those of the glosso-pharyngeal above and the spinal accessory nerve below, and belong to the lateral series of His. Its afferent fibres, like those of the glosso-pharyngeal, represent two elements. The lower ganglion has possible connexions with epibranchial sense-organs—the rest of the nerve representing the fused branchial branches of fishes. The **superior laryngeal nerve** is looked upon as the branchial nerve of the **fourth**, and the **inferior laryngeal nerve** as the branchial nerve of the **fifth arch**. While the relation of the nerve to the hinder gill-arches and clefts makes it possible to understand the innervation by the vagus of the heart and lungs, no satisfactory explanation is forthcoming of the passage of the nerve into the abdomen, and its distribution to the stomach and other organs below the diaphragm.

The **spinal accessory nerve** consists of two parts. The *accessory portion* of the nerve consists of efferent fibres for the **branchial region**, in series with the lateral motor roots of the glosso-pharyngeal and vagus nerves. The *spinal portion* of the nerve is also composed of efferent fibres, and represents the only lateral motor elements arising from the spinal cord.

Olfactory Nerve.—There is absolute uncertainty regarding the morphology of this nerve. It consists of three elements: (1) the **olfactory bulb**, derived from the cerebral hemisphere, solid in man, but a hollow cerebral diverticulum in certain animals, and forming the rhinencephalon; (2) the **olfactory ganglion**, with its central and peripheral processes, derived from the ectoderm; (3) the **nasal pit**. Attention has been specially fixed on the olfactory ganglion, which has been compared to (1) a dorsal spinal ganglion, derived from the anterior end of the medullary groove; and to (2) a lateral line sense-organ.

The **optic nerve** also presents an insoluble problem in regard to its morphological position in the series of cranial nerves. The optic stalk and optic cup have been regarded as a highly-modified dorsal ganglion; but there is insuperable difficulty in accepting this view. The peripheral processes do not become connected with either ectodermal or mesoblastic structures, but become the tissue of the retina; while the central processes, growing backwards, envelop the optic stalk, and obtain connexions with the brain. The retina must be regarded as a highly-modified layer, morphologically in series with the wall of the fore-brain; and the ectodermal structure of superficial origin comparable to the olfactory ganglion or the auditory vesicle is the lens (which may possibly be homologous with a lateral line sense-organ). The optic nerve, optic commissure, and optic tract are then to be looked upon as cerebral commissures, and not as nerves in the ordinary sense.

The simplest and most primitive condition of the head, in relation to the morphology of the cranial nerves, is found before the formation of the gill-clefts, when the salient features are a tubular and simple brain, and a series of superficial invaginations which pass from the surface inwards to become connected with outgrowths corresponding to them from the primitive brain. On either side of the head three hollow invaginations occur:—(1) The **nasal pit** bearing the olfactory epithelium becomes connected by the olfactory ganglion with the rhinencephalon, an outgrowth from the fore-brain, and so forms the basis of an olfactory organ and nerve; (2) a similar invagination produces the **lens**, connected with a protrusion of the optic vesicle from the fore-brain, by which the basis of the eye and the optic nerve is formed; (3) behind the buccal cavity a third invagination forms the **auditory vesicle**, which is connected with the solid extension from the hind-brain of the acoustic ganglia, to form the essentials of the organ of hearing and auditory nerve.

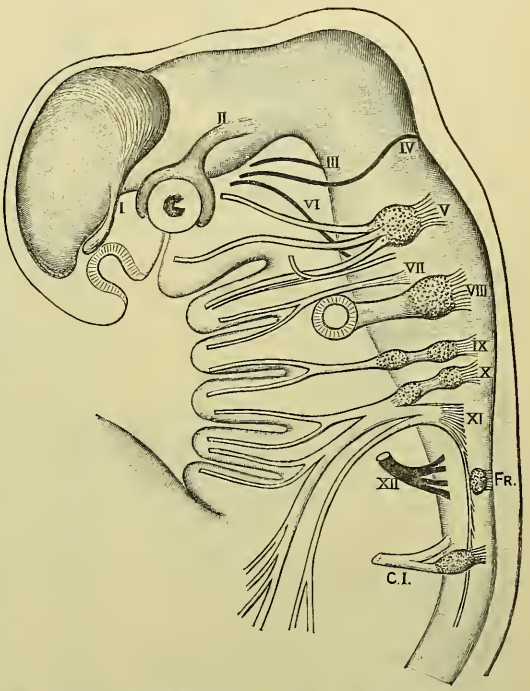


Fig. 539.—Scheme to illustrate the Embryological Arrangement of the Cranial Nerves.

I. to XII. Cranial Nerves; Fr, Froriep's ganglion; CI., Roots and trunk of the first cervical nerve.

The trigeminal nerve is essentially the nerve of the buccal cavity and the subordinate cavities, nasal and oral, derived from it. The **branchial arches and clefts** are secondary structures, and their nerves are (1) the trigeminal for the first (mandibular) arch and the cleft in front of it; (2) the facial for the second (hyoid) arch and cleft; (3) the glosso-pharyngeal for the third (thyro-hyoid) arch and cleft; and (4) the pneumogastric for the succeeding arches and clefts. The bulbar part of the spinal accessory nerve is inseparable from the motor portion of the vago-glosso-pharyngeal nerves; the spinal part is beyond the series of the cranial nerves.

Lastly, there are certain truly **segmental nerve elements**, motor fibres which, remaining associated with certain persistent cephalic myotomes, give rise to the oculo-motor, trochlear, abducent, and hypoglossal nerves.

THE SYMPATHETIC NERVOUS SYSTEM.

The sympathetic nervous system consists of a pair of elongated gangliated cords (nervi sympathici), extending from the base of the skull to the coccyx; connected, on the one hand, by a series of branches to the spinal nervous system, and on the other hand giving off an irregular series of branches to the viscera. At its cephalic end each sympathetic cord is continued in a plexiform manner into the cranial cavity along with the internal carotid artery, and forms complex relation-

ships with certain cranial nerves. At their caudal ends the two sympathetic cords become joined together by fine filaments, and are connected by the coccygeal ganglion (g. impar).

The sympathetic system (1) serves to rearrange and distribute fibres derived from the cerebro-spinal system to the viscera and vessels of the splanchnic area; (2) it transmits to the cerebro-spinal system afferent fibres from the viscera; and (3) it transmits fibres to the vessels, involuntary muscles, and glands, in the course of the somatic divisions of the spinal nerves.

General Structure of the Sympathetic System.—The sympathetic system is composed of two elements—ganglia and nerve fibres.

The **ganglia** (g. trunci sympathici) are variable in number, form, size, and position. They are not definitely segmental in position, but they are always connected together by a system of narrow commissural cords of nerve fibres. A ganglion consists of a larger or smaller number of multipolar nerve cells, enclosed in a capsule of connective tissue. Each cell is provided with one *axon* and a number of *dendrites*. The axon may enter into the composition of (*a*) the commissural cord; (*b*) a central branch (gray ramus communicans); or (*c*) a peripheral branch from the sympathetic cord. These axons are commonly medullated at their origin, but become non-medullated in their course from the parent cell. Besides these ganglia, two other series of ganglia are present in connexion with the peripheral branches of the sympathetic: intermediate or **collateral ganglia**, on the branches or in the sympathetic plexuses; and **terminal ganglia**, in close relation to the endings of the nerves in the viscera.

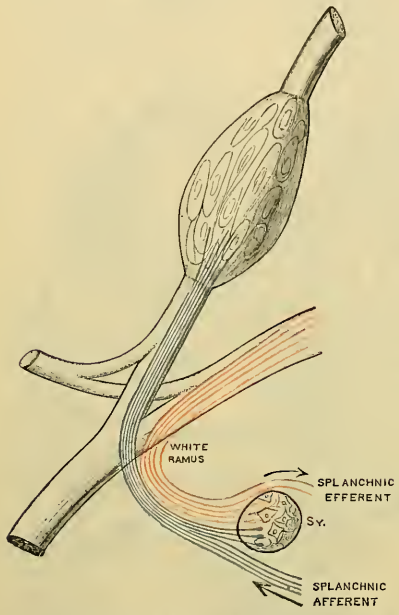


FIG. 540.— SCHEME OF THE CONSTITUTION OF THE WHITE RAMUS COMMUNICANS OF THE SYMPATHETIC.

The roots and trunks of a spinal nerve are shown, with the white ramus passing between the spinal nerve and a sympathetic ganglion (Sy). The splanchnic efferent fibres (in red) are shown, partly ending in the ganglion, and partly passing beyond the ganglion into a peripheral branch. The splanchnic afferent fibres (in blue) are shown, partly entering the ganglion, and passing upwards or downwards in the gangliated cord; partly passing over the cord into peripheral branches.

The **nerve fibres** in the sympathetic system are of two classes, medullated and non-medullated. The distinction is not absolute. The medullated fibres may lose their medullary sheaths before reaching their terminations; and the non-medullated fibres may at their origin possess a medullary sheath. The **medullated fibres** form the series of *white rami communicantes* (the visceral branches of the spinal nerves). They take origin from the anterior primary divisions of certain spinal nerves in two streams; **thoracico-lumbar** from the first or second thoracic to the second or third lumbar nerve, and **pelvic**, or **sacral**, from the second and third, or third and fourth sacral nerves. The roots of these nerves arise from both dorsal and ventral roots of the spinal nerves, but in largest numbers from the ventral root. The *fibres from the ventral root* are of very small size. They are the axons of nerve cells within the spinal cord, which enter the sympathetic cord through the white ramus, and end by forming arborisations around the cells of a sympathetic ganglion. There are three known courses for such a fibre to take in relation to the sympathetic system—(*a*) It may end in the ganglion with which it is immediately related; (*b*) it may course upwards or downwards in the commissural cord to reach a neighbouring ganglion; (*c*) it may pass beyond the gangliated cord to end in relation to cells of the peripheral (collateral) ganglia along with fibres of distribution from the sympathetic ganglia. These fibres are *splanchnic efferent fibres*; motor for the unstriped muscular tissue of the vessels and viscera, and secretory for the glands in the splanchnic area. The *fibres from the dorsal root* of the spinal nerve entering into the composition of the white ramus communicans are the axons of spinal

ganglion cells. They constitute the *splanchnic afferent fibres*, and probably traverse the sympathetic gangliated cord, passing upwards, downwards, and outwards, without being connected with its cells. They are the sensory fibres for the viscera, which they reach along with the peripheral branches arising from the sympathetic cord itself. It is not certain that fibres from the dorsal ganglia are only found in connexion with nerves provided with distinct white rami. Similar medullated fibres are found also in the gray rami communicantes.

The **non-medullated fibres** in the sympathetic system are derived from the axons of the sympathetic ganglion cells. They have different destinations. (*a*) Some fibres appear to contribute to the *formation of the commissural cord* connecting the ganglia together, and to end in arborisations round the cells of a neighbouring ganglion. (*b*) Non-medullated fibres form a large part of the system of *peripheral (splanchnic efferent) branches*, streaming into the splanchnic area in an irregular manner, both from the ganglia and the connecting commissures. (*c*) The *gray rami communicantes* form a series of non-medullated fibres (with a small number of medullated fibres intermingled) proceeding *centrally from the ganglia to the spinal nerves*. These gray rami are found in connexion with each and all of the spinal nerves. Their origin from the gangliated cord is irregular: they may come from the ganglia or the commissure; they may divide after their origin, so that two spinal nerves are supplied from one ganglion; or two ganglia may supply branches to a single spinal nerve. The gray ramus is distributed along the somatic divisions of the spinal nerves, supplying branches to unstriped muscular fibres (vaso-motor, pilo-motor) and glands (secretory). They also provide small recurrent branches, ending in the membranes enveloping the spinal nerve-roots. Mingled with the non-medullated fibres of the gray rami are found a small number of medullated fibres, regarded as medullated sympathetic fibres, and axons from the dorsal spinal ganglia incorporated with this ramus.

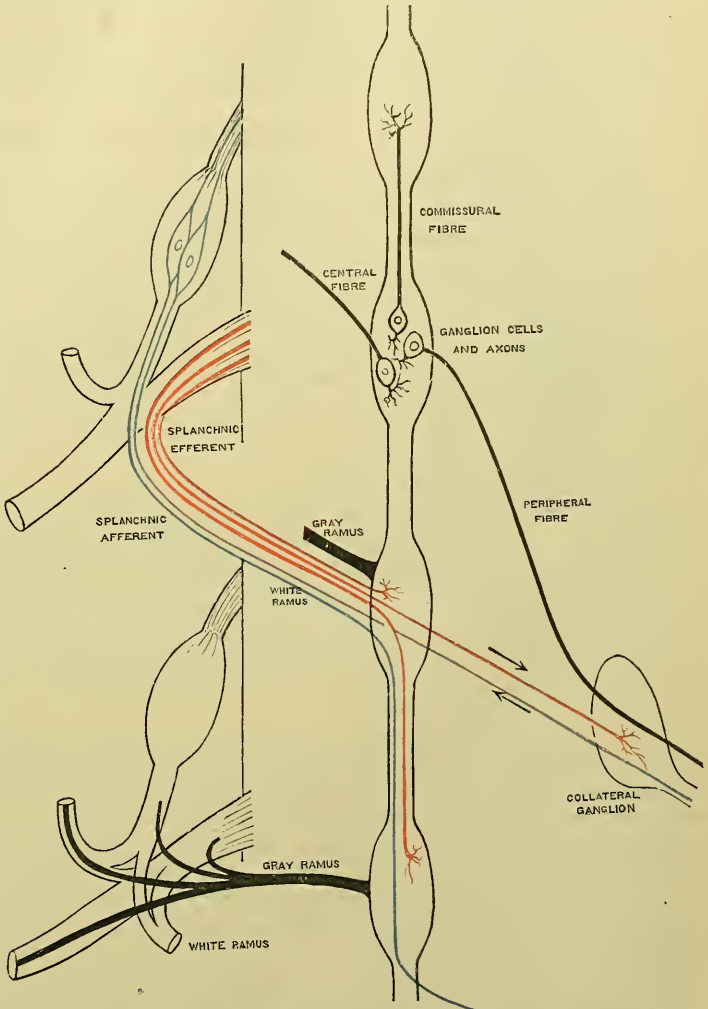


FIG. 541.—SCHEME OF THE CONSTITUTION AND CONNEXIONS OF THE GANGLIATED CORD OF THE SYMPATHETIC.

The gangliated cord is indicated on the right, with the arrangement of the fibres arising from the ganglion cells. On the left the roots and trunks of spinal nerves are shown, with the arrangement of the white ramus communicans above and of the gray ramus below.

The **commissural cords** of the sympathetic system are composed of white and gray fibres. The *white fibres* are: (1) splanchnic efferent fibres, passing to a ganglion above or below the point of entrance into the sympathetic system; (2) splanchnic afferent fibres, guided along the commissure and over or through the ganglia. The *gray fibres* are the axons of sympathetic ganglion cells: (1) true commissural fibres passing into connexion with the cells of a neighbouring ganglion; (2) fibres passing along the commissure for a certain distance upwards or downwards before entering the splanchnic area as peripheral branches.

The **peripheral (splanchnic) branches** from the sympathetic cord consist of—(1) white fibres—splanchnic afferent fibres unconnected with cells, and splanchnic efferent fibres which, after passing over the gangliated cord, are on their way to join peripheral (collateral) or terminal ganglia in relation to the viscera; and of (2) gray fibres, splanchnic efferent branches, the axons of sympathetic ganglion cells distributed to the vessels and viscera in the splanchnic area.

THE CERVICAL PART OF THE SYMPATHETIC CORD.

The cervical part of the sympathetic cord may be regarded as an upward prolongation of the primitive sympathetic system along the great vessels of the neck. It is characterised by the absence of **white rami communicantes** connecting it with the cervical spinal nerves. Its spinal fibres ascend in the commissural cord from the upper thoracic nerves to be connected with the cells of the cervical ganglia. The branches from the ganglia in the neck are distributed to structures in the head, neck, and thorax: (1) motor fibres to involuntary muscles (*e.g.* dilator of the pupil); (2) vaso-motor fibres along the arteries of the head and neck and upper limbs; (3) pilo-motor fibres along the cervical spinal nerves to the skin of the head and neck; (4) cardio-motor fibres; (5) and secretory fibres (for the submaxillary gland).

The gangliated cord in the neck is placed upon the prevertebral muscles and behind the carotid vessels. It extends from the root of the neck, where it is continuous behind the subclavian artery with the thoracic portion of the cord, to the base of the skull, where it ends in the formation of plexiform branches upon the internal carotid artery. It consists of a narrow commissural cord composed of medullated and non-medullated fibres, on which are two or three ganglia—a superior ganglion at the upper end, an inferior ganglion at the point of junction with the thoracic portion of the cord, and an intermediate middle ganglion varying in position and often absent.

The **superior cervical ganglion** (g. cervicale superius) situated at the base of the skull, lies between the internal jugular vein and the internal carotid artery. It is the largest of the sympathetic ganglia, measuring an inch or more in length. The commissural cord connects it with the **middle ganglion** (g. cervicale medium), which is of small size, is frequently absent, and may be divided into two parts. It is usually placed over the inferior thyroid artery as it passes behind the carotid sheath.

The **inferior ganglion** (g. cervicale inferius) is joined by the commissural cord to the middle (or superior) ganglion above, and is only imperfectly separated from the first thoracic ganglion below. It is of considerable size, irregular in shape, and is placed behind the first part of the subclavian artery in the interval between the last cervical transverse process and the neck of the first rib.

The **branches** from the cervical sympathetic ganglia and cord are divisible into two sets—(*A*) Central communicating branches for other nerves; (*B*) peripheral branches of distribution, which alone, or along with other nerves, form plexuses, accompanying and supplying vessels and viscera of the head, neck, and thorax. Although this distinction is made, it is to be borne in mind that the branches of communication are as much nerves of distribution as the others.

Superior Cervical Ganglion.

Central Communicating Branches.—1. **Gray rami communicantes** pass from the ganglion to the anterior primary divisions of the first four cervical nerves.

2. **Communications with Cranial Nerves.**—Just outside the skull, in the deep

part of the neck, communicating branches pass to the following cranial nerves: (*a*) to the petrous ganglion of the glosso-pharyngeal and the ganglion of the root of the pneumogastric (n. jugularis); (*b*) to the ganglion of the trunk of the pneumogastric; (*c*) to the hypoglossal nerve.

Peripheral Branches of Distribution.—1. **Pharynx.**—A **pharyngeal branch** courses downwards and inwards behind the carotid sheath to reach the wall of the pharynx, where it joins (along with the pharyngeal branches of the glosso-pharyngeal and pneumogastric nerves) in the formation of the **pharyngeal plexus**, and assists in supplying the muscles and mucous membrane of the pharynx.

2. **Heart.**—The **superior cervical cardiac** branch is a slender nerve which, on the *right side*, descends behind the large vessels into the thorax to join the deep cardiac plexus. On the *left side* the course of the nerve is similar in the neck, but in the superior mediastinum it passes between the left carotid and subclavian arteries, and over the aortic arch, to join with the inferior cervical cardiac branch of the pneumogastric in the formation of the superficial cardiac plexus. In their course both nerves form connexions with the other cervical cardiac nerves of the sympathetic, and with cardiac and other branches of the pneumogastric (external and inferior laryngeal).

3. **Vessels.**—(*a*) The **external carotid branch** passes forwards to the external carotid artery, and forms the **external carotid plexus**, which supplies offsets to that artery and its branches, as well as to the inter-carotid body. From the subordinate plexuses on the facial and middle meningeal arteries sympathetic fibres are supplied to the submaxillary and otic ganglia respectively.

(*b*) The **internal carotid branches** form an upward prolongation of the ganglion, which applies itself in the form of bundles of nerve-fibres to the internal carotid artery as it enters the carotid canal in the temporal bone. The branches separate into outer and inner parts, which form plexuses investing the artery in the cranium. The outer division forms the lower or **carotid plexus** (pl. caroticus internus); the inner division gives rise to the upper or **cavernous plexus** (pl. cavernosus). Both plexuses supply offsets to the artery and its branches, and form communications with certain cranial nerves.

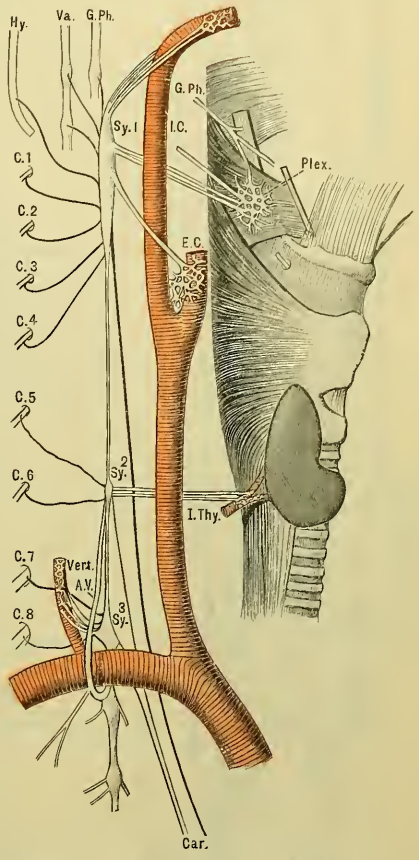


FIG. 542.—THE DISTRIBUTION OF THE SYMPATHETIC GANGLIATED CORD IN THE NECK.

Sy.1, Superior cervical ganglion, and connexions and branches; I.C, Internal carotid artery; G.Ph, Glosso-pharyngeal; Va, Vagus; Hy, Hypoglossal; C.1, 2, 3, 4, First four cervical nerves; Plex, Pharyngeal plexus; G.Ph, Glosso-pharyngeal nerve; E.C, To external carotid artery; Sy.2, Middle cervical ganglion, connexions, and branches; C.5, 6, Fifth and sixth cervical nerves; I.Thy, Inferior thyroid artery; A.V, Ansa Vieussenii; Sy.3, Inferior cervical ganglion, connexions, and branches; C.7, 8, Seventh and eighth cervical nerves; Vert, Vertebral plexus; Car, Cardiac branches.

The **carotid plexus** communicates by fine branches with (*a*) the abducent nerve, and (*b*) the Gasserian ganglion, and gives off (*c*) the great deep petrosal and (*d*) the small deep petrosal nerves. The **great deep petrosal nerve** joins the great superficial petrosal nerve from the geniculate ganglion of the facial, over the foramen lacerum medium. By their union the **Vidian nerve** is formed, which, after traversing the Vidian canal, ends in Meckel's ganglion. The **small deep petrosal nerve** passes to the **tympanic plexus**. This plexus, formed by the small deep petrosal nerve, the tympanic branch of the glosso-pharyngeal, and a twig

from the geniculate ganglion of the facial nerve, is placed on the inner wall of the tympanum. It supplies the mucous lining of the tympanum and Eustachian tube; and the **small superficial petrosal** nerve passes from it to the otic ganglion.

The **cavernous plexus** communicates with (*a*) the oculo-motor, and (*b*) the trochlear nerves, and (*c*) the ophthalmic division of the trigeminal nerve; it also (*d*) supplies twigs to the pituitary body, and (*e*) forms the sympathetic root of the ciliary ganglion. This may pass to the ganglion independently, or it may be incorporated in the long root of the ganglion from the nasal branch of the ophthalmic nerve.

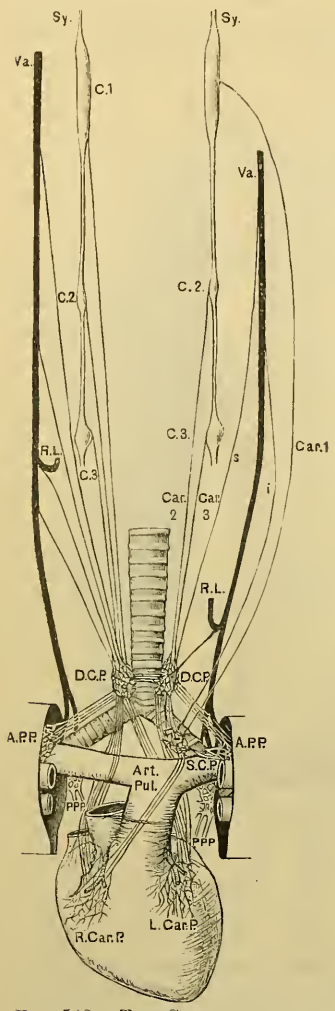


FIG. 543.—THE CONSTITUTION OF THE CARDIAC PLEXUSES.

Sy, Cervical sympathetic cord; C.1, Superior, C.2, Middle, and C.3, Inferior cervical ganglia; Car. 1, Superior, Car. 2, Middle, and Car. 3, Inferior cervical cardiac sympathetic branches; Va, Pneumogastric nerve; R.L, Recurrent laryngeal nerve; s, Superior, and i, Inferior cervical cardiac branches of vagus; D.C.P, Deep cardiac plexus; S.C.P, Superficial cardiac plexus; A.P.P, Anterior pulmonary plexus; P.P.P, Posterior pulmonary plexus; R.Car.P, Right, and L.Car.P, Left coronary plexuses; Art.Pul, Pulmonary artery.

MIDDLE CERVICAL GANGLION.

Central Communicating Branches.—1. **Gray rami communicantes** arise from the ganglion or from the cord for the anterior primary divisions of the fifth and sixth cervical nerves. 2. The subclavian loop (**ansa Vieussenii**) is a loop of communication from this ganglion, which, after passing over and supplying offsets to the subclavian artery and its branches, joins the inferior cervical ganglion.

Peripheral Branches of Distribution.—1. **Heart.**—A slender **middle cervical cardiac branch** descends, either separately or in company with other cardiac nerves, behind the large vessels into the thorax, where it ends in the deep part of the cardiac plexus on each side.

2. **Thyroid Body.** — Branches extend inwards along the inferior thyroid artery to supply the thyroid body.

When the middle ganglion is absent the branches described arise from the commissural cord.

INFERIOR CERVICAL GANGLION.

Central Communicating Branches.—1. **Gray rami communicantes** arise from this ganglion for the anterior primary divisions of the seventh and eighth cervical nerves. 2. The **subclavian loop** already mentioned connects the middle and inferior ganglia over the front of the subclavian artery. 3. A communication frequently occurs with the inferior laryngeal nerve.

Peripheral Branches of Distribution.—1. **Heart.**—An **inferior cervical cardiac branch** is given off on each side to enter the deep cardiac plexus.

2. **Vessels.**—(*a*) The **vertebral plexus** is a dense plexus of fibres surrounding the vertebral artery and accompanying its branches in the neck and the cranial cavity. (*b*) The **subclavian plexus** is derived from the subclavian loop, and supplies small offsets to the subclavian artery. It gives branches to the internal mammary artery, and communicates with the phrenic nerve.

THE THORACIC PART OF THE SYMPATHETIC CORD.

The thoracic part of the sympathetic cord consists of a variable number of ganglia of an irregularly angular or fusiform shape, joined together by commissural

cords of considerable thickness. The number of ganglia is usually ten or eleven; but the first and sometimes others may be so fused with the neighbouring ganglia as to still further reduce the number. This part of the sympathetic cord is characterised by its union with the thoracic spinal nerves. Each thoracic nerve, with the possible exception of the first, sends a **visceral branch** (white ramus communicans) to join the gangliated cord in the thorax. These white rami separate into two main streams in relation to the sympathetic cord. Those of the *upper five* nerves are for the most part directed upwards to be distributed through the cervical part of the sympathetic gangliated cord in the manner already described. The white rami of the *lower thoracic* nerves are for the most part directed downwards in the lower part of the sympathetic cord and its branches, to be distributed in the abdomen; at the same time some of their fibres are directly associated with the supply of certain thoracic viscera,—lungs, aorta, œsophagus.

These white rami are composed of (1) **splanchnic afferent fibres** passing from its peripheral branches through the sympathetic cord into the dorsal ganglia of the spinal nerves—medullated nerve-fibres unconnected with sympathetic ganglion cells; and (2) **somatic** and **splanchnic efferent fibres,** small medullated nerves which, after a longer or shorter course in the gangliated cord or its peripheral branches, become connected with the sympathetic ganglion cells, or with the cells of peripheral (collateral or terminal) ganglia, from which again (non-medullated) axons proceed to supply branches to viscera and vessels. The ultimate destination of the upper stream of white rami from the thoracic nerves has been mentioned in the description of the cervical sympathetic; the peripheral branches supplying thoracic organs contain vaso-motor fibres for the lungs and aorta. The peripheral branches from the lower part of the sympathetic cord in the thorax, receiving white rami from the lower thoracic nerves, are mainly destined for distribution to structures below the diaphragm. They comprise (*a*) viscero-inhibitory fibres for the stomach and intestines; (*b*) motor fibres for part of the rectum; (*c*) pilo-motor fibres for the lower part of the body; (*d*) vaso-motor fibres for the abdominal aorta and its branches, and

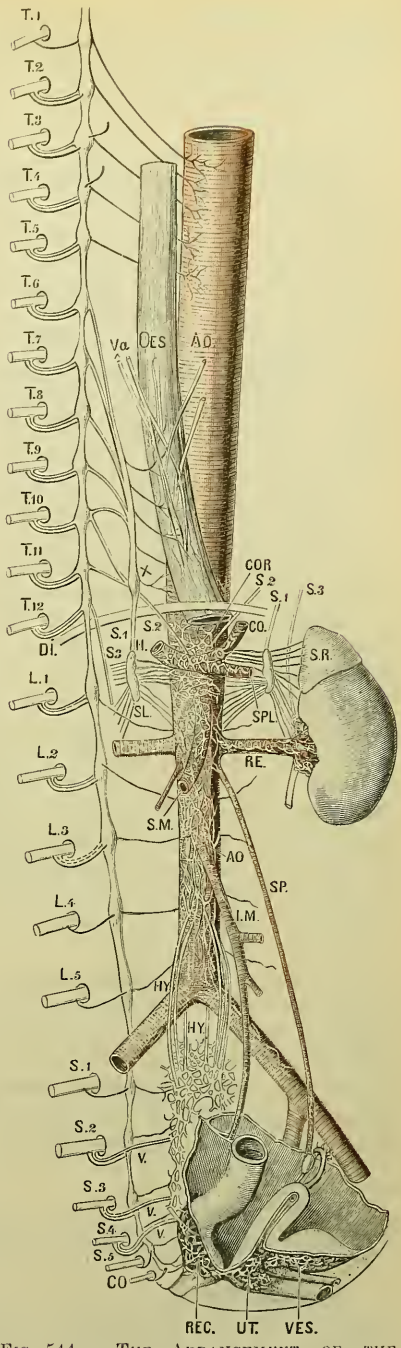


FIG. 544. — THE ARRANGEMENT OF THE SYMPATHETIC SYSTEM IN THE THORAX, ABDOMEN, AND PELVIS.

T.1-12; L.1-5; S.1-5; Co, Anterior primary divisions of spinal nerves, connected to the gangliated cord of the sympathetic by rami communicantes, white (double lines) and gray (single lines); OES, (Esophagus and œsophageal plexus; AO, Aorta and aorta plexus; Va, Vagus nerve joining œsophageal plexus; S.1, Great splanchnic nerve; X, Great splanchnic ganglion; S.2, Small splanchnic nerve; S.3, Least splanchnic nerve; Co, Coronary artery and plexus; SPL, Splenic artery and plexus; H, Hepatic artery and plexus; SL, Semilunar ganglion; Di, Diaphragm; S.R, Suprarenal capsule; RE, Renal artery and plexus; S.M, Superior mesenteric artery and plexus; SP, Spermatic artery and plexus; I.M, Inferior mesenteric artery and plexus; HY, Hypogastric nerves and plexus; REC, Rectal plexus; UT, Uterine plexus; VES, Vesical plexus; V.V.V, Visceral branches from sacral nerves.

for the lower limbs; (*e*) secretory, and (*f*) sensory fibres for the abdominal viscera. The thoracic part of the sympathetic cord is placed upon the heads of the ribs, and is covered over by the pleura.

The **branches** from the gangliated cord are, as in the neck, divisible into two sets—(*A*) Central branches, communicating with other nerves, and (*B*) peripheral branches, distributed in a plexiform manner to the thoracic and abdominal viscera.

Central Communicating Branches.—The **white rami communicantes** from the thoracic nerves have already been described. Passing forwards from the beginning of the anterior primary divisions of the nerves, they become connected with the ganglia or the commissural cord of the sympathetic.

The **gray rami communicantes** are branches arising irregularly from each thoracic ganglion, which, passing backwards along with the white rami, join the anterior primary divisions of the thoracic nerves.

Peripheral Branches of Distribution.—These branches arise irregularly from the ganglia and the commissural cord. They are composed of non-medullated fibres (splanchnic efferent) derived from the ganglion cells, and medullated fibres (splanchnic efferent and afferent) derived directly from the white rami, without the intervention of the cells of the ganglia.

1. **Pulmonary Branches.**—From the gangliated cord opposite the second, third, and fourth ganglia fine filaments arise which join the posterior pulmonary plexus.

2. **Aortic Branches.**—The upper part of the thoracic aorta receives fine branches from the upper five thoracic ganglia.

3. **Splanchnic Nerves.**—Three nerves arise from the lower part of the gangliated cord, partly from the ganglia themselves, and partly from the commissural cord between the ganglia. Passing downwards over the bodies of the thoracic vertebræ they pierce the diaphragm, to end in the abdomen.

(*a*) The **great splanchnic nerve** (n. splanchnicus major) arises from the gangliated cord between the fifth and ninth ganglia. By the union of several irregular strands a nerve of considerable size is formed, which descends in the posterior mediastinum, and piercing the crus of the diaphragm, joins at once the upper end of the *semilunar ganglion* of the solar plexus. In its course in the thorax the **great splanchnic ganglion** (g. splanchnicum) is formed upon the nerve. It is more prominent in the fœtus than in the adult. From both nerve and ganglion branches arise in the thorax for the supply of the œsophagus and descending thoracic aorta (Fig. 544).

(*b*) The **small splanchnic nerve** (n. splanchnicus minor) arises from the gangliated cord opposite to the ninth and tenth ganglia. It passes over the bodies of the lower thoracic vertebræ, pierces the diaphragm near or along with the great splanchnic nerve, and ends in the **solar plexus** (*aortico-renal ganglion*).

(*c*) The **least splanchnic nerve** (n. splanchnicus imus) arises from the last thoracic ganglion of the sympathetic, or it may be a branch of the smaller splanchnic nerve. It pierces the diaphragm, and ends in the *renal plexus*.

THE LUMBAR PART OF THE SYMPATHETIC CORD.

The lumbar part of the sympathetic cord is placed upon the bodies of the lumbar vertebræ, internal to the origins of the psoas muscle, and in front of the lumbar vessels. It is connected with the thoracic portion of the cord by an attenuated commissural cord, which either pierces or passes behind the diaphragm. It is continuous below with the sacral portion of the cord by a commissure, which passes behind the common iliac artery. It is joined by medullated fibres (white rami communicantes) from the first two lumbar spinal nerves, and it contains as well medullated fibres continued down from the lower part of the thoracic gangliated cord, and derived from the visceral branches (white rami communicantes) of the lower thoracic nerves. This part of the gangliated cord is characterised by great irregularity in the number of the ganglia. They are usually four in number, but there are frequently more (up to eight); and in extreme

cases fusion may occur to such an extent that the separation of individual ganglia becomes impossible.

White rami communicantes.—The first two (or three) lumbar spinal nerves possess visceral branches which form white rami communicantes joining the upper lumbar ganglia or the gangliated cord. These nerves form the lower limit of the thoracico-lumbar visceral branches of the spinal nerves. They comprise vaso-motor fibres (for the genital organs), and motor fibres for the bladder and uterus.

Central Communicating Branches.—**Gray rami communicantes** pass from the gangliated cord to the anterior primary divisions of the lumbar nerves in an irregular manner. One ramus may divide so as to supply branches to two adjacent spinal nerves; or a spinal nerve may be joined by two to five separate gray rami from the gangliated cord.

The rami course beneath the origin of the psoas magnus muscle and over the bodies of the vertebræ. Gray rami sometimes pierce the fibres of the psoas muscle.

Peripheral Branches of Distribution.—From the lumbar gangliated cord numbers of small branches arise irregularly, and pass inwards to supply the abdominal aorta, reinforcing the **aortic plexus** (from the solar plexus).

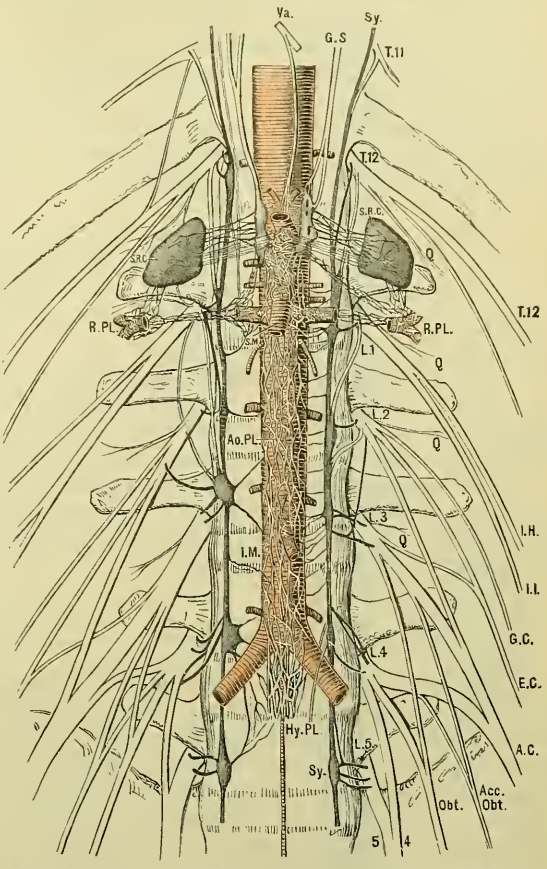


FIG. 545.—THE LUMBAR PORTION OF THE SYMPATHETIC GANGLIATED CORD AND LUMBAR PLEXUS. (From a dissection.)

T.11, T.12, L.1, L.2, L.3, L.4, L.5, Anterior primary divisions of spinal nerves, with white and gray rami communicantes.

Sy, Sympathetic gangliated cord; Va, Vagus nerve; G.S, Great splanchnic nerve, joining semilunar ganglion; S.R.C, Suprarenal capsule and plexus; R.Pl, Renal plexus; Ao.Pl, Aortic plexus; S.M, Superior mesenteric plexus; I.M, Inferior mesenteric plexus; Hy.Pl, Hypogastric plexus; Q, Nerves to quadratus lumborum; I.H, Ilio-hypogastric nerve; I.I, Ilio-inguinal nerve; G.C, Genito-crural nerve; E.C, External cutaneous nerve; A.C, Anterior crural nerve; Acc. Obt, Accessory obturator nerve; Obt, Obturator nerve 4, 5, Lumbo-sacral cord.

THE SACRAL PART OF THE GANGLIATED CORD.

The sacral part of the gangliated cord, like the cervical and lower lumbar portions of this system, receives no white rami communicantes from the spinal nerves. The **visceral branches** (*pelvic splanchnic*) of the third, and usually, also the second or fourth sacral nerves, enter the pelvic plexus without being directly connected with the gangliated cord. These nerves, however, are to be regarded as homologous with the white rami communicantes of the thoracico-lumbar nerves (*abdominal splanchnic*). They convey to the pelvic viscera—(1) motor and inhibitory fibres for rectum, uterus, and bladder, (2) vaso-dilator fibres for the genitals, and (3) secretory fibres for the prostate gland.

This portion of the cord is placed in front of the sacrum, internal to the anterior sacral foramina. It is connected above by a commissural cord with the lumbar portion of the sympathetic, and below it ends in a plexiform union over the coccyx with the cord of the other side, the two being frequently connected by the **ganglion impar** or **coccygeal ganglion**. The number of ganglia is variable; there are

commonly four. They are of small size, gradually diminishing from above downwards.

Central communicating branches arise irregularly in the form of **gray rami communicantes** from the sacral ganglia, and join the anterior primary divisions of the sacral and coccygeal nerves.

Peripheral Branches of Distribution.—(1) **Visceral branches** of small size arise from the upper part of the gangliated cord, and pass inwards to join the **pelvic plexus** (see below).

(2) **Parietal branches,** also of small size, ramify over the front of the sacrum, and form, in relation to the middle sacral artery, a plexiform union with branches from the gangliated cord of the other side.

SYMPATHETIC PLEXUSES.

It has already been seen that the peripheral branches of the sympathetic gangliated cord throughout its length are characterised by forming or joining plexuses in their neighbourhood.

The **cervical sympathetic ganglia** and nerves give rise to the carotid and cavernous plexuses; the external carotid, pharyngeal, thyroid, vertebral, and subclavian plexuses; and they send important branches to the cardiac plexuses (described along with the pneumogastric nerve).

The **thoracic ganglia** send branches to join the pulmonary and œsophageal plexuses (described along with the pneumogastric nerve). They form plexuses on the thoracic aorta, and by means of the splanchnic nerves they form the chief source of the solar plexus.

The Solar and Pelvic Plexuses.

These great plexuses serve to distribute nerves to the viscera and vessels of the abdominal and pelvic cavities. Taken together they include three plexuses—the solar plexus, hypogastric plexus, and the pelvic plexuses. They are constituted by peripheral branches of the lower thoracic, lumbar, and upper sacral parts of the gangliated cord of the sympathetic; and they are related to the central nervous system by means of the visceral branches (white rami communicantes) of the lower thoracic and upper lumbar nerves on the one hand, and by the visceral branches of the second and third, or third and fourth sacral nerves, on the other hand. The thoracico-lumbar series join the sympathetic cord, and reach the solar plexus mainly through the splanchnic nerves, and to a lesser extent through the lumbar gangliated cord. The sacral series enter the pelvic plexus without connexion with the sympathetic cord. The hypogastric plexus serves as a connecting link between the solar and pelvic plexuses.

The **solar plexus** lies on the posterior abdominal wall in relation to the abdominal aorta and behind the stomach. It is composed of three elements: the **cœliac plexus** surrounding the origin of the cœliac axis between the crura of the diaphragm, and two **semilunar ganglia,** each lying on the corresponding crus of the diaphragm, and overlapped by the suprarenal capsule, and on the right side by the inferior vena cava. The plexus is continuous with subordinate plexuses, diaphragmatic, suprarenal, renal, superior mesenteric and aortic; and by means of **the hypogastric nerves** the aortic plexus becomes continued into the **hypogastric plexus,** which again forms the chief origin of the **pelvic plexuses.**

The **semilunar ganglia** constitute the chief ganglionic centres in the solar plexus. They are irregular in form. They are often partially subdivided, and one detached portion at the lower end is named the **aortico-renal ganglion.** Other small scattered masses of cells are present in the cœliac plexus (**ganglia cœliaca**). At the upper end the semilunar ganglion receives the great splanchnic nerve. The aortico-renal ganglion at its lower end receives the smaller splanchnic nerve. Branches from the ganglion radiate in all directions—inwards to join the cœliac plexus, upwards to form the diaphragmatic plexus, outwards to the suprarenal plexus, downwards to the renal, superior mesenteric, and aortic plexuses.

The **cœliac plexus** forms a considerable plexiform mass surrounding the cœliac axis. It consists of a dense meshwork of fibres with ganglia intermingled (g. cœliaca), joined by numerous branches from the semilunar ganglion on each side, and by branches from the right pneumogastric nerve. It is continuous below with the superior mesenteric and aortic plexuses. Investing the cœliac axis, it forms subsidiary plexuses which accompany the branches of the artery. The **coronary plexus** supplies branches to the œsophagus and stomach; the **hepatic plexus** supplies branches to the liver and gall-bladder, stomach, duodenum, and pancreas; and the **splenic plexus** sends offsets to the spleen, pancreas, and stomach.

Subordinate plexuses are formed on the aorta and its branches by nerves derived from the solar plexus (semilunar ganglia and cœliac plexus).

a. The **diaphragmatic plexus** consists of fibres arising from the semilunar ganglion, and accompanies the inferior phrenic artery. Besides supplying the diaphragm, it gives branches to the suprarenal plexus, and (on the right side) to the inferior vena cava, (on the left side) to the œsophagus. It communicates on each side with the phrenic nerve. At the junction of the plexus and the phrenic nerve of the right side a ganglion is formed (**diaphragmatic ganglion**).

b. The **suprarenal plexus** is of most considerable size. It is mainly derived from branches of the semilunar ganglion, reinforced by nerves from the lower part of the solar plexus which stream outwards on the capsular arteries. It is joined by branches from the diaphragmatic plexus above and from the renal plexus below. The nerves enter the substance of the suprarenal capsule.

c. The **renal plexus** is derived from (1) branches of the semilunar ganglion, and (2) fibres from the aortic plexus, extending outwards along the renal artery to the hilum of the kidney. It receives also the least splanchnic nerve, and is connected by numerous branches to the suprarenal plexus.

d. The **superior mesenteric plexus** is inseparable above from the cœliac plexus, and is joined on either side by fibres from the semilunar ganglion. It is continuous below with the aortic plexus. A separate detached ganglionic mass (**superior mesenteric ganglion**) is present in

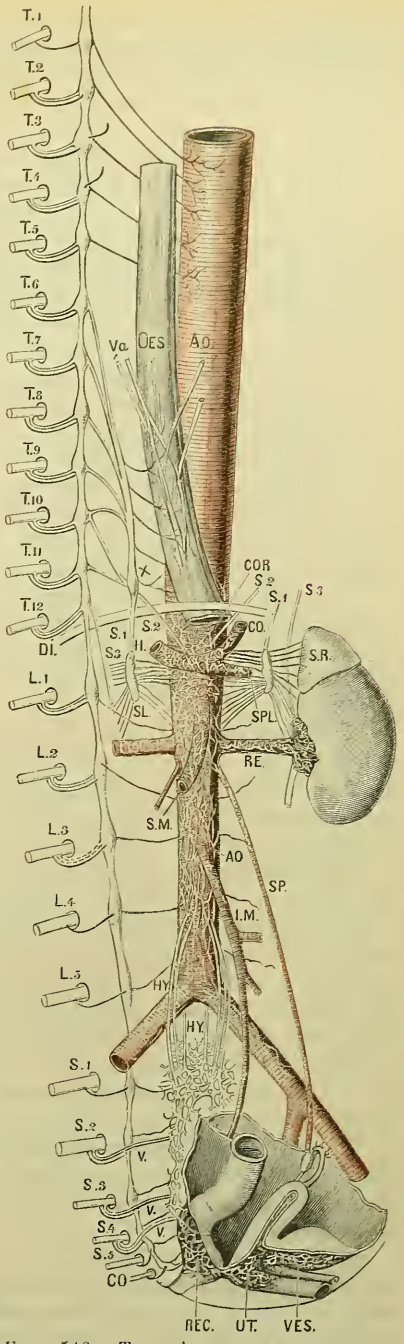


FIG. 546.—THE ARRANGEMENT OF THE SYMPATHETIC SYSTEM IN THE THORAX, ABDOMEN, AND PELVIS.

T.1-12; L.1-5; S.1-5; Co, Anterior primary divisions of spinal nerves, connected to the gangliated cord of the sympathetic by rami communicantes, white (double lines) and gray (single lines); OES, Œsophagus and œsophageal plexus; AO, Aorta and aortic plexus; Va, Vagus nerve joining œsophageal plexus; S.1, Great splanchnic nerve; X, Great splanchnic ganglion; S.2, Small splanchnic nerve; S.3, Least splanchnic nerve; CO, Coronary artery and plexus; SPL, Splenic artery and plexus; H, Hepatic artery and plexus; S.L, Semilunar ganglion; DI, Diaphragm; S.R, Suprarenal capsule; RE, Renal artery and plexus; S.M, Superior mesenteric artery and plexus; SP, Spermatic artery and plexus; I.M, Inferior mesenteric artery and plexus; HY, Hypogastric nerves and plexus; REC, Rectal plexus; UT, Uterine plexus; VES, Vesical plexus; V.V.V, Visceral branches from sacral nerves.

the plexus. Accompanying the superior mesenteric artery the plexus forms subordinate plexuses around the branches of the vessel. The plexuses in the mesentery at first surround the intestinal arteries, but near the intestine they form fine plexuses between the layers of the mesentery, from which branches pass to the wall of the gut. This plexus supplies the small intestine, cæcum, vermiform appendix, ascending and transverse portions of the colon.

e. The **aortic plexus** is the continuation downwards of the solar plexus around the abdominal aorta. It is continuous above with the superior mesenteric and solar plexuses; it is reinforced by the peripheral branches of the lumbar gangliated cord of the sympathetic; and it is connected with the hypogastric plexus below by the **hypogastric nerves.** Besides investing and supplying the aorta, the plexus contributes to various subordinate plexuses on the branches of the artery. It contributes to the suprarenal and renal plexuses, and it gives rise to the spermatic or ovarian and the inferior mesenteric plexuses.

The **spermatic plexus** invests and accompanies the spermatic artery. It is derived from the aortic plexus, and receives a contribution from the renal plexus. It supplies the spermatic cord and testicle.

The **ovarian plexus** in the female arises like the spermatic plexus. It accompanies the ovarian artery to the pelvis, and supplies the ovary, broad ligament, and Fallopian tube. It forms communications in the broad ligament with the **uterine plexus** (from the pelvic plexus), and sends fibres to the uterus.

The **inferior mesenteric plexus** is a derivative from the aortic plexus, prolonged along the inferior mesenteric artery. It forms subordinate plexuses on the branches of the artery (colic, sigmoid, and superior hæmorrhoidal), and is distributed to the descending colon, iliac colon, pelvic colon, and upper part of the rectum.

The **hypogastric nerves** form the continuation of the aortic plexus into the pelvic cavity. They consist of numerous plexiform bundles of nerve-fibres which descend along the front and back of the bifurcation of the aorta and the origin of the common iliac arteries, and over the sacral promontory, where, becoming inextricably mingled, they constitute the hypogastric plexus.

The **hypogastric plexus** is continued downwards in front of the sacrum on either side of the rectum, and ends in the pelvic plexuses.

The **pelvic plexuses** are formed by the separation of the hypogastric plexus into two halves on either side of the rectum. Each is joined by fibres from the upper part of the sacral portion of the gangliated cord of the sympathetic, and by the **visceral branches** (white rami communicantes) from the second and third or third and fourth sacral nerves. Accompanying the internal iliac artery and its branches each pelvic plexus gives off subordinate plexuses for the pelvic viscera.

a. The **hæmorrhoidal plexus** supplies the rectum, and joins the superior hæmorrhoidal plexus from the inferior mesenteric plexus.

b. The **vesical plexus** accompanies the vesical arteries to the bladder-wall. Besides supplying the muscular wall and mucous membrane of the bladder, it forms subordinate plexuses for the lower part of the ureter, the vesicula seminalis, and the vas deferens.

c. The **prostatic plexus** is of considerable size. It is placed on either side of the gland, and in addition to supplying its substance and the prostatic urethra, it sends offsets to the neck of the bladder and the vesicula seminalis. It is continued forwards on each side to form the **cavernous plexus** of the penis (plex. cavernosus penis). Bundles of nerves pierce the layers of the triangular ligament, and after supplying the membranous urethra at the root of the penis, give off branches which enter and supply the corpus cavernosum. The cavernous nerves communicate with branches of the pudic nerve, and give offsets to the corpus spongiosum and the spongy portion of the urethra.

d. The **uterine plexus** passes upwards for a short distance with the uterine artery between the layers of the broad ligament, and is then distributed to the surfaces and substance of the organ. It communicates between the layers of the broad ligament with the ovarian plexus.

The **vaginal plexus** is formed mainly by the visceral branches of the sacral

nerves entering the pelvic plexus. It supplies the wall and mucous membrane of the vagina and urethra, and provides a **cavernous plexus** for the clitoris (plex. cavernosus clitoridis). The uterine and vaginal plexuses of the female correspond to the prostatic plexus of the male.

DEVELOPMENT OF THE SYMPATHETIC SYSTEM.

There are two diametrically opposite views of the mode of development of the sympathetic system.

In birds and mammals the first rudiment of the sympathetic cord occurs in the formation of a longitudinal unsegmented column of mesoblastic cells (which stain more deeply than the mesoblast in which they lie) on either side of the aorta, and coterminous with it. This column of cells becomes joined at an early stage by the **visceral branches** of the spinal nerves which grow inwards from the main nerve trunks into the splanchnic area, and result from the division of the nerve into somatic and visceral parts. These visceral branches constitute the **white rami communicantes**. They receive contributions usually from both dorsal and ventral roots, and gradually approaching the above-mentioned column of mesoblastic cells, they become intimately associated with the cells. In some cases fibres of the visceral nerves pass over the cellular column into the splanchnic area without connexion with it (Fig. 548). By the junction of these visceral nerves with the cells of the column, certain cells persist and produce the **ganglia**. The intervening portions of the column, by changes in the cells, and by the addition possibly of fibres belonging to the visceral nerves, give rise to the **commissural cords**. The cellular column, besides producing the gangliated cord, by the further growth of its cells and their extension centrally and peripherally, produces the **gray rami communicantes**, parts of the **peripheral branches**, and the **peripheral** (collateral and terminal) **ganglia**, as well as the medullary portion of the **suprarenal capsule**. The cervical, lower lumbar, and sacral portions of the sympathetic gangliated cord are secondary extensions from the more primitive condition, gradually growing upwards and downwards along the main vessels. These portions of the system are not provided with white rami communicantes. The ganglia of the sympathetic assume their segmented appearance (1) from the persistence of the primitive cells and their connexion with the spinal nerves by means of the white and gray rami communicantes, and (2) from the way in which the primitive column is moulded by the surrounding structures (bones, segmental arteries, etc.)

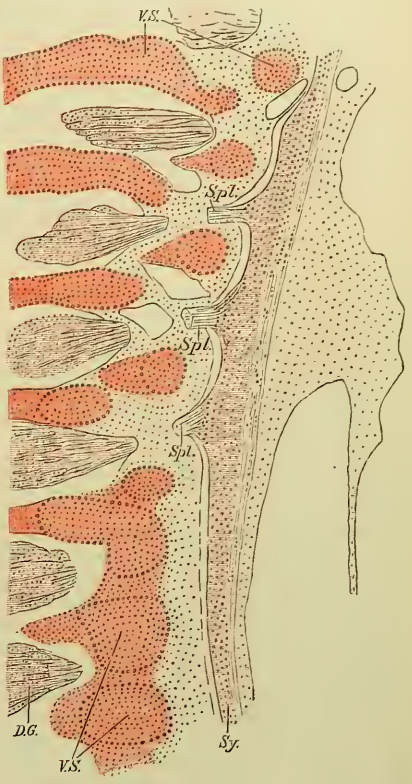


FIG. 547.—THE DEVELOPMENT OF THE SYMPATHETIC GANGLIATED CORD.

Sy, Sympathetic cord; Spl, Splanchnic branches of spinal nerves (white rami communicantes); V.S, Vertebral segments; D.G, Dorsal ganglia.

Another account of the development of the sympathetic system, supported by high authority, describes the gangliated cord as an outgrowth of the dorsal ganglia of the spinal nerves. It is said that each ganglion gives off a bud at its lower end, which, growing inwards into the splanchnic area, becomes attached to the trunk of the spinal nerve just beyond the union of the dorsal and ventral roots. The bud still extending inwards into the splanchnic area, remains associated with the nerve by an attenuated stalk. These buds, it is said, become the ganglia, which, after reaching their permanent place in the splanchnic area, are supposed to extend upwards and downwards so as to coalesce and form a beaded chain of ganglia. The stalks connecting the ganglia with the spinal nerves become the white rami communicantes. This mode of development does not satisfactorily account for several important features of the sympathetic system—the development of those parts of the gangliated cord which possess no white rami, the

absence of a real segmental character in the cord (remarkably shown in the fœtus), and the constancy of continuity in the gangliated cord. No instance is recorded of a hiatus between two ganglia. It is a tempting view on the other hand, as it ascribes to the one germinal layer (epiblast) the formation of all the elements of the nervous system, and it brings the sympathetic ganglia into serial homology with isolated ganglia on the cranial nerves (*e.g.* the ciliary, spheno-palatine, and otic, on the trigeminal nerve).

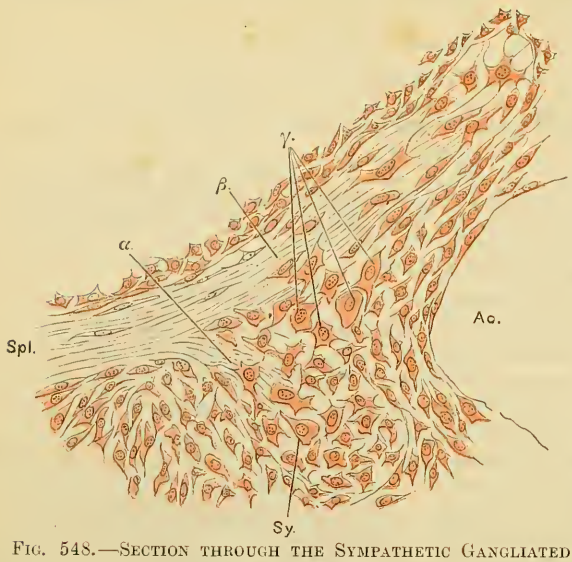


FIG. 548.—SECTION THROUGH THE SYMPATHETIC GANGLIATED CORD OF AN EMBRYO.

Showing the connexion with the ganglion (Sy) of the white ramus communicans (Spl); (α) a portion of the ramus joining the ganglion; (β) fibres passing over the cord, accompanied by a stream of cells; (γ) continuous with those of the ganglion; (Ao) Aorta.

The Morphology of the Sympathetic System.

From a consideration of its structure, functions, and development, there appear to be two separate structures represented in the sympathetic nervous system—the **spinal** and the **sympathetic elements**. The structure of the system presents a union of two distinct elements—fibres of cerebro-spinal origin and "sympathetic" cells and fibres. While the function of the gangliated cord and its branches seems to be absolutely dependent upon the cerebro-spinal nervous system, it is certain that the cells and fibres of the sympathetic system possess a vital activity apart from their connexion with the central nervous system. In the development of the sympathetic it is at least highly probable that a mesoblastic rudiment or precursor forms the basis of the sympathetic system, which is secondarily joined by nerve-fibres from the roots of the spinal nerves.

Morphologically this part of the nervous system is essentially a longitudinal cord or column, associated with involuntary muscles and glandular tissues, and particularly related to the organs in the splanchnic area. Like other longitudinal structures in the body, and especially like the organs of the splanchnic area, the sympathetic system is not truly segmental. The gangliated cord is only quasi-segmental, the segmentation being attributable to its junction with the visceral branches of the spinal nerves. The peripheral branches from the gangliated cord are not segmental; even the gray rami are not properly metameric, but, like the ganglia, assume a segmental character in consequence of their connexions with the spinal nerves.

The phylogenetic relation of the sympathetic and the cerebro-spinal elements in the system it is impossible to determine. It may be that the sympathetic system is the representative of an ancient architecture independent of the cerebro-spinal nervous system, the materials of which are utilised for a more modern nervous system; or it may be that the correlation of spinal nerves and sympathetic are both the consequences of the formation of new organs and structures in the splanchnic area. Examined in every light, it possesses features which effectually differentiate it from the cerebro-spinal system, although it has become inextricably united with it and subservient to it.

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